Issued June 25, 1909.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 112.
A. D. MELVIN, CHIEF OF BUREAU.

THE LOCO-WEED DISEASE OF THE PLAINS.

BY

C. DWIGHT MARSH,
Expert, Poisonous-Plant Investigations,
Bureau of Plant Industry.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., January 16, 1909.

Sir: I have the honor to transmit herewith, for publication as a bulletin of this Bureau, a manuscript entitled "The Loco-Weed Disease of the Plains," by Dr. C. Dwight Marsh, expert, of the Office of Poisonous Plant Investigations, Bureau of Plant Industry, being a report of field investigations carried on during 1905, 1906, and 1907.

Although the work reported in this paper was done under the supervision of the Bureau of Plant Industry, it has been considered desirable, inasmuch as it deals largely with subjects coming within the scope of the Bureau of Animal Industry, such as the symptomatology, pathology, and treatment of a disease of animals, to have it published as a bulletin of the latter Bureau.

For many years the so-called loco disease has been a cause of heavy loss to the stockmen of the West, and it has been generally attributed by them to certain plants eaten by the stock. As far back as 1886 the Bureau of Animal Industry investigated the subject, and an article by Dr. M. Stalker in the Third Annual Report of the Bureau has up to the present time remained the most satisfactory published description of the disease. While Doctor Stalker in that report expressed the belief that the loco plant "is possessed of some toxic property that has a specific effect on the nerve centers," and while these plants have long been classed as poisonous in the publications of this Department, it has remained for Doctor Marsh in the work herein reported to present experimental proof that the plants have a poisonous effect and really cause the disease and to suggest a line of treatment, and for Dr. A. C. Crawford, in Bulletin 129 of the Bureau of Plant Industry, to discover and identify barium as a poisonous element in the plants.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Washington, D. C., July 10, 1908.

Sir: I take pleasure in handing you herewith, for publication as a bulletin of the Bureau of Animal Industry, the accompanying manuscript presenting a technical report entitled "The Loco-Weed Disease of the Plains," prepared by Dr. C. Dwight Marsh, expert, working under the direction of Dr. Rodney H. True, Physiologist in Charge of Poisonous-Plant Investigations in the Bureau of Plant Industry.

This bulletin presents the evidence obtained from an experimental field study of the relation of the so-called "loco weeds" to the losses frequently attributed to the eating of them by horses, cattle, and sheep. The plants studied are those characteristic of the plains, and work has been carried on under actual field and corral conditions. The investigation has been fully successful in proving the suspected plants to be the cause of great and widely scattered stock losses. It has made possible a satisfactory description of the disease and furnishes a basis on which other disorders, now confused with loco-weed disease, but of different origin, may be distinguished from it. It has developed a method of successfully treating a large percentage of loco cases when such occur under circumstances making the frequent handling of the animals practicable.

A companion bulletin, dealing with the technical laboratory studies carried on at the same time in Washington by Dr. A. C. Crawford, pharmacologist, is a necessary supplement to this bulletin for anyone desiring a full account of the loco-weed disease. This bulletin is entitled "Barium, a Cause of Loco-Weed Poisoning," and constitutes Bulletin No. 129 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Dr. A. D. Melvin,
Chief, Bureau of Animal Industry.

PREFACE.

The so-called "loco-weed disease" of horses, sheep, and cattle has been a source of most serious complaint for many years, especially from such stockmen as have grazed their animals on the Great Plains east of the Rocky Mountains. While the losses have varied in severity from year to year, they have reached such a magnitude as to make the matter one of national concern. On account of both the economic importance of the problem and of its intrinsic scientific interest numerous investigations approaching the subject from the most varied standpoints have been undertaken. As a net result there has appeared a large body of literature marked by a wide diversity in the conclusions reached. This discouraging state of disagreement prevailed among the reported results of the field studies on the subject prior to the time at which the Office of Poisonous Plant Investigations undertook its campaign, but it was believed that by laying siege to the problem in a more thoroughgoing and persistent way than any of its predecessors had been in a position to do it might still be able to ascertain the essential facts of the loco situation.

Accordingly, in 1905 a field station was established at Hugo, Colo., in cooperation with the Colorado Agricultural Experiment Station, which furnished the animals used, and experimental feeding work on horses and cattle was begun. The state of opinion both among practical stockmen and among scientists had made clear the first step to be taken. Popular opinion had long pointed to the eating of certain members of the pea family (Leguminosæ), especially *Astragalus mollissimus*, the purple loco weed, and to *Aragallus lamberti*, the rattleweed, as the probable cause of poisoning. The first task was to test the accuracy of this report. Accordingly feeding experiments under field and corral conditions on plants of known origin were undertaken at Hugo, and parallel laboratory tests were carried on at Washington. The results showed clearly that loco symptoms were produced as a result of loco-weed feeding, and as the investigation proceeded the characteristics of this chronic, progressive disease were thoroughly worked out.

The disagreement above referred to arose from a number of causes, not least of which was the kind of animal upon which the investigations had been carried out. Those working on sheep had seen much reason to regard the symptoms observed as fully accounted for by the various kinds of animal parasites with which this animal

is affected in regions in which the loco disease has been regarded as prevalent. Another reason for disagreement lay in the fact that the characteristic symptoms of the loco-weed disease had not been sharply presented as a result of the experimental production of the disease; hence "loco" has been a general term covering many kinds of trouble of a more or less chronic type. Indeed, there seems to be good reason for believing that in some cases starvation has been called "loco." Another source of confusion has lain in the fact that investigators taking a more or less superficial view of the matter had seen animals in various stages of the disorder and had not gone into the matter deeply enough to correlate the different phases of a progressive disease.

The second stage of the field work looked forward to measures of relief. The behavior of the plants concerned was looked into and methods of eradication tried. Contrary to frequently expressed belief, these weeds were found to be easy of extirpation by thoroughly digging them out. Methods of meeting the trouble from the standpoint of the animals concerned were in a degree worked out.

Laboratory work carried on at Washington seemed to show that the loco plants collected in the vicinity of the Hugo station—and doubtless those of eastern Colorado, Nebraska, and Kansas—owe their poisonous character, to a certain degree, to the presence in them of barium absorbed from the soil. For a fair understanding of the loco situation both the bulletin herewith presented, dealing with the field phase of the work, and the companion publication on "Barium, a Cause of the Loco-Weed Disease," based on the laboratory work, must necessarily be taken into account. Unfortunately the nature of these conclusions was not indicated until near the close of the work for the season of 1907, so that the work in the direction of remedial measures gained no advantage from this information. Those measures which were found to be most beneficial are shown, however, by the light from the laboratory result, to be well founded. The field work has been carried out by Dr. C. Dwight Marsh, expert, and his assistants, the laboratory work by Dr. A. C. Crawford, pharmacologist.

The present work by Doctor Marsh consists of a technical report on prolonged field feeding investigations in connection with the loco problem, carried out at Hugo and Woodland Park, Colo., and Imperial, Nebr., in cooperation with the Colorado Agricultural Experiment Station and the Nebraska Agricultural Experiment Station. Doctor Marsh has here succeeded in working out very completely and more thoroughly than has ever been done heretofore the symptomatology of the true loco disease, and has given a basis on which to distinguish the trouble known as loco, properly speaking, from various types of pseudo-loco which have gone under this name. He has also described the plants which cause the trouble and outlined their distribution.

The experiments intended to secure the extermination of the plants are summarized, the conclusion of which is that the most practicable way of disposing of the plants is to dig them out. This can be done on land which is taken up by settlers, and will relieve a large number of sufferers. The question of the open range, in so far as it is still Government property, is one which we see no way of handling except by Federal appropriation.

The treatment of animals is also outlined, it appearing that horses and cattle require somewhat different handling. Horses are helped by daily treatment with Fowler's solution, and cattle do best with slight daily doses of strychnin, accompanied with laxative feed and occasional doses of magnesium sulphate. Further work is planned on wholesale antidoting under range conditions.

R. H. True,

Physiologist in Charge, Poisonous-Plant Investigations,

Bureau of Plant Industry.

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THE LOCO-WEED DISEASE OF THE PLAINS.

PART I.—INTRODUCTION.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

The word "loco" is of Spanish origin, in which language it is used both as a noun and as an adjective, meaning crazy. It has been popularly applied to a considerable number of plants in the semiarid region of the Western and Southwestern States because of the effects these plants are supposed to produce on animals.

The first published account of the loco plants was by Doctor Vasey in the monthly report of the Commissioner of Agriculture for October, 1873. He quotes a letter from O. B. Ormsby, of Bakersfield, Cal., who describes the effect of the plant in the following terms:

> It prevails quite abundantly over an extent of 150 square miles in this valley, and, I am informed, is found in other valleys of the State, and also in Arizona. This year the army-worm, and a minute insect which destroys the seeds, have killed a great deal of it, but if not molested it will soon flourish to as great an extent as ever. I think very few, if any, animals eat the loco at first from choice; but, as it resists the drought until other feed is scarce, they are at first starved to it, and after eating it a short time appear to prefer it to anything else. Cows are poisoned by it as well as horses, but it takes more of it to affect them. It is also said to poison sheep. As I have seen its action on the horse, the first symptom of the poisoning, apparently, is hallucination. When led or ridden up to some little obstruction, such as a bar or rail lying in the road, he stops short, and, if urged, leaps as though it were four feet high. Next he is seized with fits of mania, in which he is quite uncontrollable, and sometimes dangerous. He rears, sometimes even falling backward, runs or gives several successive leaps forward, and generally falls. His eyes are rolled upward until only the white can be seen, which is strongly injected, and, as he sees nothing, he is as apt to leap against a wall or man as in any other direction. Anything which excites him appears to induce the fits, which, I think are more apt to occur in crossing water than elsewhere, and the animal sometimes falls so exhausted as to drown in water not over 2 feet deep. He loses flesh from the first, and sometimes presents the appearance of a walking skeleton. In the next and last stage, he only goes from the "loco" to water and back, his gait is feeble and uncertain, his eyes are sunken, and have a flat, glassy look, and his coat is rough and lusterless. In general, the animal appears to perish from starvation and constant excitement of the nervous system, but sometimes appears to suffer acute pain, causing him to expend his strength in running wildly from place to place, pawing and rolling, until he falls, and dies in a few minutes.

The specimen sent, Doctor Vasey said, was an Astragalus. In the report of the Commissioner of Agriculture for 1874 Doctor Vasey quotes this same letter of Ormsby and refers to other reports received from California. The plants sent to him were determined as *As-*

tragalus hornii Gr. and *Astragalus lentiginosus* Gr. He states, too, in this report that Doctor Moffatt, of the United States Army, had sent in specimens of *Oxytropis lamberti*, from Colorado, with the following description of its effects:

> Cattlemen inform me that a weed grows among the grass, particularly in damp ground, which is poisonous to horned cattle and horses and destroys many of them. From the manner in which they describe its effects upon the animals it must be of the nature of a narcotic, and they assure me that cattle, after having eaten it, may linger many months or for a year or two, but invariably die at last from the effects of it. The animal does not lose in flesh apparently, but totters on its limbs and becomes crazy. While in this condition, a cow may lose her calf and never find it again and will not recognize it if presented to her. The sight becomes affected, so that the animal has no knowledge of distance, but will make an effort to step or jump over a stream or an obstacle while at a distance off and will plunge into it or walk up against it upon arriving at it. The plant was pointed out to me, and seems to be related to the lupin.

In 1875 Mr. Kellogg, in an article on California and Colorado loco poisons, in the Proceedings of the Academy of Sciences of California, states that thousands of horses, cattle, and sheep have been poisoned by *Astragalus menziesii* in California. He gives a description also of *Oxytropis lamberti*.

Professor Prescott in 1878 gave an account of the attempts of Miss Watson to extract a poisonous principle from *Oxytropis lamberti*. He states that Mr. Birdsall tried some of the ground root on himself, but with little effect.

In an article in the American Journal of Pharmacy in 1879 Maisch adds *Astragalus mollissimus* to the list of loco plants, and says that he is informed that horses dig in the earth for it, become intoxicated, seek water, drink with avidity, swell up, fall over, and die.

In the report of the Commissioner of Agriculture for 1878 Professor Collier refers to specimens of *Oxytropis lamberti*, which he says were received for examination. He makes a brief reference to the work of Miss Watson.

In 1880 Professor Collier, in the report of the chemist to the Commissioner of Agriculture for 1879, makes a preliminary report on *Astragalus mollissimus* and *Oxytropis lamberti*. He states that as a result of the analyses the only substances likely to be poisonous in *Astragalus mollissimus* are an alkaloid and a bitter extractive; the harm being done by *Oxytropis lamberti* probably, by the fact that the sweet taste of the plant leads the animals to eat a substance which is mechanically unfit for food, but it is possible that if the animal becomes enfeebled the small amount of alkaloids present may produce poisonous effects.

Ott, in 1882, in an article in "New Remedies" states that the loco plants are *Oxytropis lamberti*, *Astragalus mollissimus*, and *Sophora sericea*. These may prove fatal in two or three days; other

cases linger a year or more. Horses are more affected than cattle or sheep. When first eaten an exhilarating effect is produced which tempts the animal to eat more. Later the animal contracts the habit. It does not acquire the habit in summer when there is an abundance of grass. He then states that the effects are as follows:

1. A small amount of exercise will produce profuse sweating.
2. The animal when "shying" at an object is very liable to rear up and fall backward.
3. A stroke, or even a touch, about the head seems to rouse the disorder, which is immediately manifested by struggles and general frenzy.
4. While being ridden, when that is possible, the animal steps very high, as though walking over obstacles, and the slightest thing in the road, as a stick, piece of rope, or wagon rut, will be magnified into an apparently insurmountable difficulty, and it is ludicrous to see the animal jump as though leaping over a ditch in an effort to get over it.
5. The animal loses all power of reasoning or of coordination, will walk into a ditch or bank instead of around it, and will sometimes walk backward when apparently trying to go forward.

Ott made an alcoholic extract of *Astragalus mollissimus* and treated subcutaneously frogs, rabbits, and a cat. The rabbits were used for circulation tests. He summarizes the results of his pharmacological tests as follows:

1. It decreases the irritability of the motor nerves.
2. It greatly affects the sensory ganglia of the central nervous system, preventing them from readily receiving impressions.
3. It has a spinal tetanic action.
4. It kills mainly by arrest of the heart.
5. It increases the salivary secretion.
6. It has a stupefying action on the brain.
7. It reduces the cardiac force and frequency.
8. It temporarily increases arterial tension, but finally decreases it.
9. It greatly dilates the pupil.

In 1885 Mohr gives the distribution of the species, stating that they are found in New Mexico, Colorado, Utah, Nevada, Arizona, and California. He gives the following list of species as loco plants: *Astragalus mortoni*, *A. hornii*, *A. lentiginosus* var. *fremontii*, *A. cocarpa* (*oocarpa* probably intended), *A. crotalariæ*, and *Oxytropis lamberti*.

Up to this time all reports agree as to the poisonous character of the plants, but an anonymous author in the American Veterinary Review of 1885 states positively that the plant is not poisonous. He says that when cattle eat a quantity it absorbs the juices of the alimentary canal and dries them up. It then collects in the stomach and intestines as a dry mass, and the pressure on the circulation causes all the symptoms observable and finally produces death. He declares that the internal condition of cattle with this disease verifies this view.

Havard in 1885 says that *Astragalus mollissimus* is the loco plant of western Texas. Animals avoid it, and eat it only through inadvertence or necessity. They lose appetite, become stupid and thin, have tremors, and lose coordination. *Oxytropis lamberti* is found only in northern Texas, and is nowhere common.

Hurd in 1885 states that the loco plants in California are *Astragalus crotalariæ*, *A. lentiginosus*, and *Oxytropis lamberti*. He says, too, that animals eat loco only when driven by hunger, but they soon crave it and wander miles in search of it. They become intoxicated, can not be led through a gate, walk mincingly, shy, have an unsteady gait, and become ataxic; when driven into water they may lie down and refuse to rise. They become emaciated and finally die of exhaustion. Complete recovery never occurs.

In the Cornhill Magazine of 1886 there is an article entitled, "The cowboy at home," in which is a somewhat detailed description of the phenomena of loco poisoning in horses, as follows:

> We passed a heap of about 40 dead horses piled up together, the most revolting, pitiful spectacle imaginable, and standing listlessly, or moving about with staggering gait, were about twice as many more still living creatures with a peculiar look and manner about them such as I had never seen before, and most of whom must surely soon be dragged to the big heap close by. But what on earth did it all mean? It seemed so strange suddenly to come across this grewsome sight on the lone prairie. I soon learned the explanation.
>
> A weed called "loco" has of late years largely increased in some of the cattle ranges of Texas and the Indian Territory, owing, probably, to an increase in the rainfall. It has a mysterious habit of appearing suddenly in places where it was before unknown, and, given a dry season, of as suddenly disappearing. During the summer, when the prairie is a fair expanse of waving grass, lit up with bright flowers, both horses and cattle instinctively avoid it, but when in the fall of the year the grass becomes scarce in overstocked regions, and when all around assumes a brown and burnt-up appearance, it stands out conspicuously and temptingly green, its long, soft, velvety leaves rising in a bunch from 6 inches to a foot off the ground. Then the hungry creatures begin by nibbling, suspiciously and stealthily, at the seductive plant, but very soon become reckless, and eagerly and greedily devour all that comes in their way. And now, if the mania can not be nipped in the bud by a sufficiency of good strong food, the animal is doomed, for he has become a confirmed "loco-eater." He will rapidly become thin and lose all control over his movements; he will be subject to frequent fits, during which he lies on the ground groaning and foaming at the mouth; he throws himself about without reason; rears up or runs about in small circles when you attempt to mount him; his eyes turn dull and stupid; in short, he gives you the impression of being bereft of his senses. Specimens of loco have been subjected to analysis by experts in Washington and in Edinburgh, but without anything injurious being discovered in it. It is possible that some minute animalculæ may be the cause of the mischief, but up to the present its disastrous effects only are known, for this pernicious weed causes periodically the death of thousands of horses and cattle.

Professor Sayre, of the University of Kansas, in 1886 published in the Transactions of the Kansas Academy of Sciences a somewhat extended account of loco and locoed animals. He visited New Mexico, Colorado, and Kansas, and states that the plant appears at

Medicine Lodge and extends southwesterly into the Indian Territory and northwesterly through Kansas. He says that a veterinary surgeon, Doctor Harding, took two horses with a taste for loco, and kept one in a pasture with loco and the other in a loco-free pasture, with the result that the one died and the other recovered. Two others were fed, one with hay and the other with dead loco. The first one lived and the second died. He gives a description of the symptoms of locoed animals, the result of his personal inquiry among ranchmen and the report of a Mr. R. E. Steele. It is somewhat interesting, however, that many parts of this description agree word by word, and sentence by sentence, with a letter of Mr. Ormsby quoted in Vasey's report of 1873.

Sayre states that the loco disease is due to two plants, *Astragalus mollissimus* and *Oxytropis lamberti*. He made a preliminary chemical examination which was apparently never completed. He also held an autopsy on a locoed cow belonging to Mr. Steele. The cow was undersized, poor, stupid, unsteady, with short breathing and shaking head. He reports that the reticulum and psalterium were softened. The tissues through the intestines were degenerated; the peritoneum and the omentum were inflamed with tumors the size of a pea; the heart was one-third larger than normal, with the mitral and tricuspid valves inflamed; the bile was thin and watery, and the inner coat of the bladder softened; the membranes of the brain were congested and adherent, the brain was paler than normal, and the membranes of the spinal cord were inflamed and adherent. He concludes that the disease is one of the mucous and serous membranes.

In the same year Professor Sayre published an article in the report of the Kansas State board of agriculture, which was, to a large extent, a repetition of the material published in the Transactions of the Kansas Academy of Sciences. He adds, however, a report that the plant causes abortion in cows. He states that as the result of his own chemical examination it would appear that there is no poisonous principle in the plant, and suggests that the hairs upon the leaves may be irritating.

In the Third Annual Report of the Bureau of Animal Industry for 1886 Doctor Stalker gives a report of a personal investigation of the loco disease. He visited the country from western Nebraska to Salt Lake, and from Cheyenne to El Paso. He describes the appearance and habits of the two plants, *Oxytropis lamberti* and *Astragalus mollissimus*. He states that the term loco is used simply to designate a certain disease, as well as being a term applied to plants.

He found that the loco habit is an acquired one and that animals will forget it when kept on loco-free food. All confirmed loco-eaters become complete physical wrecks, showing general derangement of the nervous system and more or less digestive disturbance. In

post-mortem examinations of horses he found a serous effusion in the lateral ventricles, hemorrhagic clots in the fourth ventricle, and sometimes a serous effusion in the arachnoid space. The liver was dense in structure. Immense numbers of bots were found, especially in the duodenum, and he suggests that while these parasites would not account for the clinical symptoms, they may have something to do with the abnormal appetite. In post-mortems on sheep large numbers of tapeworms were found, and these he suggests may account in part for the loco appetite in sheep. He presumes that the plant is possessed of some toxic property that has a specific effect on the nerve centers, and that these effects have a marked tendency to remain permanent, though he was not aware that the poison, if present, had ever been separated by analysis. He states that the disease may be cured by taking animals from the range and feeding them on nutritious diet. He also states that special attention should be given to the destruction of intestinal parasites, and expresses his belief that thousands of supposed cases of loco poisoning are the result alone of such parasites.

In 1887 Behr, in an article on the poisonous plants indigenous to California, states that the notorious loco weed is an Astragalus, but that the exact species is not known with certainty. He says that dogs, cats, and rabbits do not suffer if the seeds or herbs are mixed with their food, and that cattle, sheep, and horses suffer only at certain seasons. Poisoning may be due either to infection by some fungoid parasite, perhaps of the Claviceps order, or by a substance produced by fermentation or putrefaction, or it is possible that the poison may not be of vegetable origin at all, but caused by some parasite infesting the suspected plant.

Carhart, in the New York Medical Record in 1887, speaks of his acquaintance with the effects of loco in the Panhandle. Cattle occasionally eat it, but are rarely affected by it; mules do not suffer from it; but cow ponies die by the thousand. If the taste is acquired they will leave green grass to hunt for it. They break down rapidly, become weak, staggering, foolish, and crazy. A tap on the head will cause them to stagger, rear, and fall backward. Vision is impaired, and there is a loss of muscular coordination. The Indians say that it is due to an insect, but the author has found none. Carhart drank a decoction of loco without effect, and administered the decoction to a locoed horse with apparent good results.

In the Homeopathic Recorder in 1887 Doctor Gee gives a somewhat detailed account of some experiments made by some of his students who took doses of loco extract. There seems to be no uniformity in the reports that these students made. They tell of an infinite number of symptoms, many of which, apparently, must have been imaginary.

Dr. T. E. Wilcox, of the United States Army, writes to the Medical Record in 1887 on the subject of loco, and states that the treatment employed by the cowboys in Idaho consists in the amputation of the tails of the animals affected. They claim that they seldom lose any stock when this treatment is instituted early enough. The writer adds that paralysis is probably due to congestion of the spinal cord. It affects the posterior members first. The pupils are dark, as after the use of eserin. *Oxytropis lamberti*, *Astragalus mollissimus*, and possibly others of the Leguminosæ are charged with producing loco poisoning. In Idaho the cowboys call these plants larkspur, although true larkspur is rarely found in the line of march and at that season of the year.

Kingsley in 1888 refers to Kennedy's work, which was at that time unpublished, and gives cases of locoed mules, with report of a postmortem. In a second letter he concludes that the mules suffered from colic, and this, from his report of the symptoms and the postmortem, would seem to be probable. He concludes that the loco plant is not poisonous and that the symptoms and pathology are such as would result from overfeeding with any green feed.

Kennedy in 1888, after a description of the plant, tells of his attempts at analysis. He discovered no alkaloid and separated no poisonous principle. He experimented with infusions in boiling water, with dried powder, and with an organic acid separated from the plant. He fed these materials to a dog and there was no effect. He concludes that the plant is not poisonous and that ill effects, if any, are produced by the tough, fibrous, indigestible character of the plant acting as a foreign body, or else its action is identical with an overload of any kind.

The St. Louis Medical and Surgical Journal in an editorial article a little later refers to Kennedy's work, and criticizes him for trying physiological experiments on a dog rather than on an herbivorous animal, and considers his results of no value.

Klench in 1888 gives a general description of symptoms, referring to the papers of Sayre and Stalker, and advises as remedies the administration of potassium bromid or belladonna and aloes, and bleeding.

In 1888 Miller writes of the geographical distribution of *Oxytropis lamberti* and *Astragalus mollissimus* and gives a description of the plants. His description of the effect of the weeds, as well as his remarks in regard to the distribution, are apparently derived from Sayre's publications. He makes the suggestion that inasmuch as loco is said to produce abortion it may be that the plant might be used as an emmenagogue.

Sayre in 1888, in a paper published in the Kansas State board of agriculture report, adds to what he has written in preceding papers a summary of the results of Kennedy and of Ott, and states that he

has tried the extract on himself, but with no result. In the same year, in the Proceedings of the Kansas Pharmaceutical Association, he reports what he has written before and seriously questions the existence of poisonous properties in the plants, considering that the effects may be due to malnutrition, brought about in part by feeding on this weed.

Schwarzkopff in 1888 published his experience with locoed animals in Texas, detailing the symptoms in very much the same terms as those used by previous authors. He used as a remedy atropin and morphia sulphate applied hypodermically. The horse was quiet and acted sensibly in six days. He reports a post-mortem on another horse. He found the cranial sinuses filled with a straw-colored fluid, the vessels of the pia mater injected, and the gray substance reddened and edematous. On the base of the brain inside the arachnoid membrane he found a teaspoonful of pinkish fluid. The medulla and cord were edematous and moist on cut surface.

In 1889 McEachran reports an autopsy near Livermore, Colo. He watched 100 cases of locoed sheep at Givens Ranch, near Colorado Springs, and made post-mortem examinations of two, no details of which are published with the report.

In 1889 Anderson describes the symptoms of locoed animals. He says that the animal has unnaturally bright eyes, froths at the mouth, exhibits extreme salivation, or sometimes the mouth may be hot and dry. The appetite is lost and an offensive gas is belched forth. The animal loses control of the limbs, and sometimes the muscles of the neck are contracted on one side. It becomes stupid, falls, and rarely rises again. It may die in a few hours or lie for a week. He reports a post-mortem in which the intestines and surrounding fat were green immediately after death. The arteries and smaller vessels in the limbs were gorged with thick dark blood. The lining of the first stomach was worn and ulcerated in patches and in some cases decomposition seemed to have commenced: it was very soft and could be peeled off the muscular layer in big pieces. The lungs and heart were almost bloodless, and the brain was purplish, soft, and pulpy. He states, however, that the symptoms vary in different cases. He lists as loco plants *Oxytropis lamberti*, *Leucocrinum montanum*, *Fritillaria pudica*, and *Zygadenus elegans*.

In 1889 Dr. Mary G. Day, in two articles in the New York Medical Journal, describes the process which she followed in attempting to separate a poison from loco plants and gives the result of some pharmacological experiments with a decoction. She fed the decoction to a cat and found disturbing symptoms in two days. There was less activity, the coat became rough, the appetite was lost, fondness for loco was induced, and there was diarrhea, retching, and vomiting. Emaciation increased until the eighteenth day, when convulsions

occurred. There were alternate periods of excitement and quiet for 36 hours, when the posterior extremities became paralyzed, and the animal died in about two hours. The post-mortem examination showed ulcers in the stomach and duodenum. The heart was in diastole and anemic. In the second case she found similar symptoms but no periods of excitement. This cat died on the thirteenth day. Two cats were confined and treated in the same way, except that one was fed loco. The loco-fed animal acquired the disease, while the other remained well. In Michigan experiments on frogs and kittens caused nervous twitchings and death. A jack rabbit was fed on milk and grass, then fresh loco was substituted for the grass. It acquired the habit and died in ten days, with the head thrown back and with the stomach ruptured. Doctor Day states that more poison is present in the plants in the fall and winter. She reached the following conclusions:

1. There is some poison in loco weed which may cause the illness, and, if sufficient quantity is taken, the death of an animal.
2. This poison is contained in the decoction obtained from the plants, and by systematically feeding it to healthy cats cases of loco disease may be produced.
3. A taste for the green loco weed may be experimentally produced in the jack rabbit.
4. From the large quantity of the plant or of the decoction required to produce the disease, the poison must be weak, or, if strong, it must be in very small amount.

In the Druggists' Bulletin of 1889 is a résumé of the work on loco up to that date. Miss Day's work is criticized as valueless because of the lack of control experiments. The article is generally skeptical in regard to the existence of a specific poison in the loco plant.

In 1889 Power reported upon a chemical examination of loco, and later, in 1891, Power and Cambier made another report. The general result of their work was negative. They showed both in Astragalus and Crotalaria a very small amount of toxic alkaloids.

In 1889, in the Druggists' Bulletin, Professor Sayre reviews his preceding work in regard to the loco plants, gives drawings of two species, *Oxytropis lamberti* and *Astragalus mollissimus*, and reports the detail of a chemical examination of these plants. He also states that he has performed certain physiological experiments, but does not report them in this paper. He gives quite fully the result of the work of Doctor Ott, and then states that his own physiological experiments have all given negative results. He does not claim that the weed is not poisonous, but apparently does make the claim that nothing is proven as yet in regard to its poisonous properties.

Curtice, in 1889, in his report upon the animal parasites of sheep, quotes the report of the autopsy by Faville on locoed sheep, in which he found numbers of tæniæ. The author says that the description of locoed sheep applies equally well to those infested with tæniæ; that it is difficult to separate the symptoms of the two diseases, and

many cases of locoed animals are victims of tapeworms. That the tæniæ may tend to produce depraved appetites or the morbid craze for particular food is also a reason for suspecting that the loco disease may depend in part on the tapeworm disease.

Sayre, in 1890, in the report of the Kansas board of agriculture, gives the result of Miss Day's paper, in which she tells of the separation of crystals which she considered the poisonous principle. Sayre produced the same crystals and considers them inorganic. He says he himself has separated a crystalline organic substance but has not carried the investigation further.

An article by Pammel, in 1891, states that *Astragalus mollissimus* and *Oxytropis lamberti* are called loco plants by ranchmen. Crotalaria is the cause of loco in Iowa. In Australia a species of Gompholobium is a loco. He adds, also, as loco plants *Malvastrum coccineum* and *Physostigma venenosum*. He does not distinguish any difference in the specific effects of Astragalus and Aragallus. He also calls *Stipa viridula* a loco weed.

In 1892 McCullaugh gives a description of the pathological effects in locoed horses. He says that all herbivorous animals, even antelopes, are liable to the disease. The disease was first noticed west of the Rio Grande years ago. Since then the weed has been carried by birds and the continuity of the wind to the upper Missouri, into old Mexico, the Gulf of California, and California. The action of the plant is similar to that of alcohol or opium. The weed becomes green while the snow is on the ground. Among the first symptoms are loss of flesh, general lassitude, and impaired vision. The last may be taken as the first symptom. After the animal begins to become viciously shy an exostosis appears in the middle and superior portion of the frontal bone, becoming at times as large as a pullet's egg, and remains permanently. The animal exists in this condition from ten to eighteen months, but sometimes it will live not over three months. As the disease advances the animal loses muscular power and tetanic symptoms appear. It will invariably fall if suddenly startled. The muscles of the mouth and tongue become partially paralyzed, so that it is impossible to take food. The author has many times offered water to locoed horses that he knew had not drunk in five or six days. They would sometimes gaze stupidly for hours at a time at a trough of water, but make no attempt to drink. The true cause of death is starvation.

In 1892 Sayre, in the Thirteenth Report of the Kansas board of agriculture, after a résumé of his previous papers, states that he has been able to separate an alkaloid, but that it was not poisonous, and his conclusions are that there is a disease having a mysterious connection with Astragalus and allied genera. He quotes a letter from Professor Harshbarger, of Topeka, which states that animals hunt

loco, become nervous and later crazy; that they bite at water instead of drinking it, their eyesight becomes affected, and they become vicious and emaciated. Sayre then gives Harshbarger's opinion in regard to loco, which is skeptical and negative. He suggests that the disease may be caused by other things, as hot weather or stagnant water.

He also quotes a letter from Mr. Mayrath, of Dodge City, who states that he had 18 cattle eating loco in November, and that all died before May 1, although well fed. He says that cattle and horses eat loco for the most part in the late fall and winter; that they eat it grubs, eggs, and all. He suggests a connection of the grubby stem with the disease, and says he has been told of a man who was killed inside of twenty-four hours by loco tea.

Sayre then gives a résumé of Doctor Mayo's paper, and in conclusion gives an instance of a horse having loco disease, although it had never seen the loco plant.

Schuchardt, in 1892, in the Deutsche Zeitschrift für Thiermedicin, has an article on the loco disease of horses and cattle, in which he gives a careful and accurate résumé of the literature up to date, but adds nothing to what has been said in earlier publications.

In the same year Dr. B. F. Stalker, in the Medical Current, Chicago, states that as early as 1849 the Indians along the Missouri River told of a plant found in Kansas, Texas, and along the foothills as far north as Wyoming which would produce death, preceded by erratic forms of excitement. They said it affected cattle and horses, and the Mexicans claimed a similar effect on man. The author describes *Astragalus mollissimus* and *Oxytropis lamberti*, and states that abortion is sometimes produced by eating loco.

O'Brine, in 1893, in a bulletin of the Colorado State Agricultural College, gives a review of preceding literature, quoting especially from Faville. In 1889 *Astragalus mollissimus* and *Oxytropis lamberti* were fed to a sheep at the college, with no results. He states that the Colorado law offering a bounty for the destruction of loco plants was passed March 14, 1881, and repealed in April, 1885. It cost the State $50,000 a year.

O'Brine tried to separate the poisonous principle, and failed. He found the same reactions for alfalfa that he obtained for loco. He made tests with rabbits, with no results. He made a number of autopsies near Livermore, and found a clot at the base of the brain in all cases. He suggests that the effects of the loco are not direct, but dependent upon some digestive processes.

Williams, in 1893, in the bulletin of the South Dakota Agricultural College, gives a list of the plants supposed to cause loco in South Dakota. They include *Astragalus mollissimus*, *A. lotiflorus*, *A. bisulcatus*, *A. haydeniensis*, and *Oxytropis lamberti*. He describes the plants and general effects on the stock, quoting Vasey and Mayo.

In 1893 Professor Mayo published a general article on the subject of loco, in which he not only described the symptoms in much the same terms as former authors, but gave the results of some personal examinations of his own. He says that the old inhabitants of southwestern Kansas say it is more abundant upon ranches where Mexican sheep were pastured in an early day. He found on the roots two species of Tineidæ, and upon the plant a Bruchus and a Curculionid. He tried extracts of the dried plant and the fresh leaves on guinea pigs, but with no results. Both guinea pigs and cattle refused to eat the plant. He ate it himself with no ill effects, and concluded that the weed was not the cause of the disease, but when he made observations in the field he changed his mind. He found that animals acquire a taste, wander off alone, lose flesh, and have a stiff and stilted action of the legs. When lying down, they have difficulty in rising, the head trembles, the dependent parts of the body swell; they have a vacant stare, though they are not blind, and they do not shed their hair in the spring. They can be led only with great difficulty, shy violently, and are subject to crazy fits, especially when driven hard. Locoed animals never fully recover.

In post-mortems he found a large amount of serum in the body cavity, the intestines atonic, spleen small, liver small, pale, and adherent to the diaphragm. The rumen was full of loco. The meninges of the brain were thickened and congested. The brain was smaller than normal, and firmer, and the gray tissue was darker than normal and thinner on the cerebrum. In the central white substance of one brain were three small gelatinous translucent spots about the size of a small pea. Sections of the brain showed atrophy. Purkinje's kidney cells in some cases had disappeared; in other cases the processes were atrophied. There were no changes in the spinal cord. His conclusion was that there was no evidence of a narcotic principle in the plant, and that the animals died from malnutrition or malassimilation produced by eating the loco plants. The cause of the delirium may be clots or thrombi in the brain, as these are apt to be formed during wasting and debilitating diseases. He suggests as treatment removing the animals from loco plants and giving them some good condition powders.

In the Medical Century of 1893 Doctor Givens writes on the subject of loco, or "crazy weed," or *Astragalus mollissimus*. He describes the plant in general and the effect upon animals of eating, much as had already been described by preceding authors. He then states that he had secured from Colorado some of the dried root of *Astragalus mollissimus*, from which he prepared a tincture and tested its effect when given as a medicine upon three cases of insanity, each of which had hallucinations of sight and hearing. The net result of his investigations was that loco has no effect on insane patients, and

there is no reason to think that it can be used to advantage in the treatment of mental disorders. He concludes that it is harmless, even when taken in large doses, although it may at the same time have a poisonous action on herbivorous animals, as claimed by others.

In the report of the Canadian Experimental Farms in 1893 Fletcher mentions the fact that the subject of loco weeds has been brought to their attention by the poisoning of sheep and lambs in Manitoba, and suggests that owners of herds should send in specimens of the plants in order that the reports may be verified.

W. Thornton Parker, in 1894, describes the symptoms of loco poisoning as seen by him in Texas and New Mexico. Describing the plant, which seems to have been *Astragalus mollissimus*, he suggests that beneficial results can be obtained by treating the affected animals with muriate tincture of iron with accessories of hygienic treatment.

In the same year Professor Mayo describes much more fully than in his earlier article, and very accurately, the symptoms of loco poisoning. He speaks of the dropsical swellings which sometimes occur in the dependent parts of the body. Locoed animals walk with a peculiar creeping gait that is recognized by those familiar with the disease. No poisonous principle was found, and he reiterates his former conclusion that the loco disease is the result of malnutrition.

In 1895 Ruedi reports an examination of supposed locoed sheep in Estes Park, Colo. He found their temperatures low—between 86° and 100° F.—with breathing stertorous, pulse slow, abdomen distended, and diarrhea present. In the autopsies he found them anemic, the intestines filled with gases, the liver enlarged and filled with blood, the kidneys congested, and the bladder distended. The heart was in diastole and the brain bloodless. He prepared solutions and fed rabbits. All passed through a period of excitement which the author explains as caused by the brain anemia, followed by a period of dullness. They were observed for a period of ten days. None died, but they were killed for autopsy. In all cases there was congestion of the abdomen and anemia of the brain. He separated a base which he called "locoin" and an acid, and states that locoin is not poisonous, but that the acid is. He refers to the loco as "white loco" or *Astragalus mollissimus*. It is difficult to tell what species he was dealing with, but it seems more likely that it was *Aragallus lamberti*. It may be said in regard to his work that there seems to be no evidence that the sheep examined by him had eaten loco, and the symptoms and the autopsies lead the present author to conclude that they did not have the loco disease at all.

In 1896 Nocholds, in the American Veterinary Review, gives his experience while driving a bunch of horses from southern to north-

western Texas. Some of them gradually acquired the loco habit. One of them wandered from the bunch, walked high, had a staring coat, glassy eyes, and could not be driven. Some of them showed the effect only when excited or driven hard. All were stupid. All affected animals were mares over 6 years old, and 23 out of 300 died within a year. The author thinks there is no cure.

In 1897 Mr. J. H. Maiden, in the Report of the Department of Agriculture of Sydney, New South Wales, in a discussion of poisonous plants in that locality, mentions the "indigo disease" of Australia as probably identical with the loco disease of the United States, and in connection with this he quotes O'Brine in regard to the loco disease.

In 1898 Professor Sayre published in the Kansas Medical Journal a repetition of his former statements, and concludes with this statement: "We feel warranted in saying that the so-called poison is a development within the animal, and not a product preexisting in the weed itself."

In 1899 Prof. S. B. Nelson, of the Washington Agricultural College, in a report on experiments on feeding wild plants to sheep, states that he has fed small amounts of *Astragalus spaldingii*, *Astragalus palousensis*, and *Astragalus dorycnioides*, but without any bad results.

In the Annual Report of the Department of Agriculture of the Northwest Territories in 1899, T. N. Willing refers to the abundance of *Oxytropis lamberti* in the Territories and expresses his surprise that there is not more trouble from it.

In an article on the ethno-botany of the Coahuila Indians of southern California, Barrows in 1900 refers to the genus Astragalus, known as "rattlesnake weed" or "loco weed" in California. He says that several species are poisonous to cattle, sheep, men, and horses. One species, he states, is used by the Coahuila Indians as a flavoring principle, and according to another author dry pods are pounded up and mixed with beans and perhaps other articles of food as a spice.

In Law's work on veterinary medicine, published in 1901, is a general review of the subject of loco, concluding with a special report of Miss Day's work.

In the Annual Report of the Bureau of Animal Industry for 1900 E. V. Wilcox states that *Astragalus spicatus* is the most important loco plant of Montana. Besides this species there are *Astragalus splendens* and *Astragalus lagopus*, which are harmful. He disproves the belief that the loco disease may be caused by alkali, and gives an account of the characteristics of the disease and the details of an acute case of a sheep which died in four days. He states that the disease in cattle is rare. In autopsies on sheep a slight congestion of the brain is noticed, the fatty tissue is reduced, and the muscles

pale. Locoed sheep may be fed and fattened for mutton, but never fully recover from the disease.

In the report of Chesnut and Wilcox on stock-poisoning plants of Montana, in 1901, is a discussion much like that in the preceding paragraph. They state that the most reliable observations on the subject of loco disease indicate that it is the result of eating undue quantities of certain weeds, and express the belief that the plants contain a poisonous principle which is harmful to domestic animals. They report two experiments, feeding a Belgian hare and a sheep with extract of loco, but without results except slight narcotic effects in the rabbit.

In 1901 Mr. Maiden repeats the statements made in 1897 in the Report of the Department of Agriculture of Sydney, and adds that in all probability the "nenta disease" of South Africa is identical with the "pea-eating disease" of Australia and the loco disease of the United States.

In the report of the Oklahoma Agricultural Experiment Station of 1902 are some brief statements in regard to loco. Loco is distributed over the western half of the territory and causes considerable loss.

In the Proceedings of the Pacific Northwest Wool Growers' Association of 1902, Professor Blankinship tells briefly about the effects of eating *Oxytropis lamberti* and gives its distribution in Montana. He states particularly that the loco habit is taught to one animal by another. Hence, he says, it is very important that animals that have commenced to eat the weed should be separated from the rest of the herd.

T. N. Willing, in the Annual Report of the Department of Agriculture of the Northwest Territories in 1902, gives a cut of *Astragalus lamberti* and says that *A. lamberti* and *A. splendens* are abundant from Manitoba to the Rockies. He gives a short description of the symptoms of loco poisoning. Cattle are seldom affected.

In 1903 Professor Blankinship, in a bulletin of the Montana Agricultural Experiment Station on loco and some other poisonous plants, treats rather fully of loco in Montana. He states that the loco plant in Montana is the *Oxytropis lamberti* Pursh., or *Astragalus spicatus* (Hook.) Rydb. After referring to the distribution of the plant generally, he says that in Montana it is found up to an altitude of 8,000 feet in the country east of the Continental Divide, between Livingston on the west and Billings on the east, the mountains on the south, and north to the vicinity of the Little Belt and Highwood Mountains. Sheep are the principal sufferers from loco in Montana, horses and cattle being rarely affected, and it is the young sheep and colts that are affected rather than the older ones.

He then describes the symptoms of the disease, and, taking up the subject of prevention, reasons that because it is the younger animals that are principally affected, especial care should be taken of them. In regard to the extermination of the plant, he says it is possible to accomplish this by digging it out, as has been proved in one or two specific cases. This should be done when the plant is in bloom in order to kill the seed crop.

In 1903, Van Es and Waldron, of the North Dakota Experiment Station, in an article entitled "Some Stock Poisoning Plants of North Dakota," give a general description of the symptoms of loco poisoning which adds nothing to that of previous publications. They state that the loco plants are *Aragallus lamberti* and *Aragallus splendens*, the former being generally distributed in the State, while the latter occurs on more sterile soil and is reported only from a few counties of the State. Neither plant has caused any large amount of damage in North Dakota.

In 1904 Sayre published two papers. In the first, entitled "What is Insanity in Lower Animals?" he suggests that the symptoms of loco disease may be due to anemia, cerebral congestion, inflammation of the brain or its membranes or of the membranes enveloping the spinal cord, or to forage poisoning. In his second paper, published in the Journal of the Kansas Medical Society, he gives an analysis to determine the food value of the loco plant, but does not discuss the results of the analysis. In this paper he broaches as theories to explain the effect of loco, (1) irritation by hairs; (2) disturbance to digestion, such as might happen from any food in a weakened condition of the animals in spring; and (3) a poison developed in the process of digestion.

In 1904 J. E. Payne, of the Agricultural Experiment Station of Colorado, in a report on cattle raising on the plains, states that there is no evidence that cattle eat largely of the loco weed or are affected by it. Where these plants are prevalent the range is very poor. He further says that the talk about loco is kept up by cattle owners to keep out settlers. A number of unnamed diseases may be included under the term "loco."

In 1904 Doctor Marshall published in the Johns Hopkins Hospital Bulletin a résumé of the results of his work of the preceding two years, while in the service of the United States Department of Agriculture, in feeding locoed sheep in Montana. His conclusions may be summarized as follows: The loco disease affects horses and sheep, and occasionally cattle and goats. *Astragalus mollissimus* and *Aragallus spicatus* are the commonest loco weeds. Ranchers consider as important accessory factors: (1) Age; the disease appears before the end of the second year; (2) insufficient feed; (3) insufficient supply

of water; lack of salt; (4) general conditions of health; healthy animals never acquire the disease. He then describes the symptoms.

In this investigation only sheep were examined; all were lambs or yearlings. They did not prefer the loco. Many had bronchitis, conjunctivitis, etc. Usually the fleece was rough. All were infected with parasites. The parasites found were *Thysanosoma actinioides*, *Haemonchus* sp. (in the fourth stomach), *Metastrongylus filaria* (in the bronchioles), *Sarcocystis tenella* (in the muscles), and *Cysticercus tenuicollis* (in the peritoneal cavity). The fringed tapeworm was so abundant as to dilate the bile ducts.

He concludes that there is no true loco disease of sheep produced by the weed, but that the so-called locoed animals suffer from bad feeding, insufficient care, and a variety of other diseases, the most important of which are the parasitic diseases.

Fletcher in 1905, in evidence given before the committee on agriculture and colonization at Ottawa, Canada, stated that the loco weeds were abundant in Alberta and through to Manitoba, but are not as injurious as in Montana. He has never seen a case of loco disease in Canadian-bred animals.

In 1905 Professor Linfield, director of the Agricultural Experiment Station of Montana, in a report of a series of experiments on sheep feeding, compares the effect of feeding upon a flock of locoed sheep with the effect produced upon a flock of normal sheep. He states as his general results that the locoed sheep gained about as much as the normal sheep, but inasmuch as they were very thin at the start, it took about twice as long to get them ready for market. All these locoed sheep were treated with a vermifuge at the beginning of the experiment, and the author implies that their locoed condition may have been the combined result of poor feed and parasites. His work may be criticized, inasmuch as his figures as to gain in weight are based on the surviving locoed animals. He started with 42, and only 29 remained at the end of the experiment. He states that nearly half of this lot was lost through natural death or by killing for postmortem examinations. The fact, however, remains that his figures are based on the best of the flock, and the statistical results of the feeding experiment would probably not have appeared as favorable for the locoed animals if the whole number had been considered.

Again, in 1905, in the Proceedings of the Kansas Academy of Sciences, Sayre published a partial bibliography of the subject and repeated the report of the analysis and his theory of the causation of the disease by irritation by the hairs of the plant.

Prof. L. G. Carpenter, director of the Agricultural Experiment Station of Colorado, in the eighteenth annual report of the station (for 1904–5) states that considerable work has been done by Payne

on the subject of loco, which has made clear the necessary conditions of the experiment. He also refers to the cooperative work undertaken with the United States Department of Agriculture.

In this same publication Dr. George H. Glover, veterinarian of the Colorado Agricultural Experiment Station, gives a partial report upon the first year's cooperative work at Hugo.

Prof. S. B. Nelson in 1906 reports feeding small quantities of *Astragalus spaldingii*, *A. arrectus*, *A. purshii*, and *A. reventus*, but with no results. He suggests that longer feeding might have produced more positive results.

Prof. L. G. Carpenter, in the report of the Colorado Agricultural Experiment Station for 1906, published in 1907, gives a résumé of the work done by the United States Department of Agriculture at Hugo.

Doctor Glover, in a report of the veterinarian to the director of the Colorado Experiment Station, published in 1907, makes a brief statement also in regard to the work at Hugo.

SYMPTOMS MENTIONED IN LITERATURE.

In the preceding pages we find noted a very large number of symptoms of loco poisoning. The list below gives most of these, omitting those found by Doctor Gee in his experiment on his class, as they were almost infinite in number as well as contradictory. In this list the symptoms are arranged purposely in such a manner as to show their contradictory character.

Congestion of abdomen.
Abortion.
Anemia.
Loss of appetite.
Arteries gorged with thick, dark blood.
Bile thin and watery.
Bladder with inner coat softened.
Bladder distended.
Blindness.
Body cavities with an excess of serous fluid.
Brain atrophied.
Brain bloodless.
Brain with the membranes inflamed.
Brain congested.
Pia mater injected.
Gray tissue of brain darker than normal.
Gray substance of brain red and edematous.
Brain tissues soft and pulpy.
Sinuses of brain filled with fluid.
Lateral ventricles of brain holding serous effusion.
Fourth ventricle of brain with blood clot.
Breathing short.
Coat rough.
Winter coat retained.
Constipation.
Diarrhea.
Convulsions.
Craziness.
Hallucinations.
Lack of muscular coordination.
Emaciation.
Exostosis of frontal bone.
Eyes glassy.
Eyes dull and staring.
Pupils dilated.
Vision impaired.
High temperature.
Low temperature.
Frothing at the mouth.
Shaking head.
Impaired hearing.
Heart of increased size.
Heart with inflamed valves.

Heart bloodless.
Heart with reduced action.
High stepping.
Hyperesthesia.
Intestines filled with gases.
Intestines congested.
Intestines green.
Intestines with tissues degenerated.
Kidneys congested.
Purkinje's cells in kidneys lacking.
Difficult to lead.
Liver dense.
Liver small.
Liver enlarged.
Lungs bloodless.
Narcotized.
Stiff neck.
Irritability of motor nerves.
Decrease of irritability in sensory nerves.
General derangement of nervous system.
Paralysis of mouth or tongue.
Paralysis of hind legs.
Omentum inflamed, with tumors.
Rearing and plunging.
Shying.
Solitary habit.
Spinal cord edematous.
Spinal cord membranes inflamed and adherent.
Spleen small.
Excitement followed by depression.
Stomach ruptured.
Third stomach (psalterium) softened.
Second stomach (reticulum) softened.
First stomach (rumen) lining worn, ulcerated, and decomposed.
Swelling under the jaw.
Swelling of dependent parts of body.
Teeth loose.
Teeth not loose.
Tremors.
Tendency to turn either to the right or to the left but not in both directions.
Urine offensive.
Vomiting.
Weakness across loins.
Weakness and staggering gait.

While this list is confusing because of the number of items and the contradictions involved, yet in regard to some of the symptoms there is great uniformity. The following symptoms have been noted by a large number of observers, and in regard to them there is a fairly general agreement:

Slow, staggering gait.
Rough coat.
Staring look.
Emaciation.
Lack of muscular coordination.
Extreme nervousness, shown in shying, rearing, etc.

REMEDIES PROPOSED.

The remedies suggested for the loco disease by different writers, as would be expected from the indefinite knowledge of the subject, have been of various kinds, many of them having no logical basis. Among them are the following:

1. Potassic bromid, belladonna, and bleeding.
2. Amputation of the tail, which, of course, is simply one form of bleeding.
3. Potassium iodid and quinin, with strychnin; in some cases it may be desirable to add jaborandi or pilocarpin.
4. Blister on the top of the head with the administration of 60 grains of calomel every second or third night. The calomel should be followed by sulphate of iron.
5. A prescription of belladonna, calomel, licorice, and glycerin.
6. A prescription of iron sulphate, gentian, muriate of ammonia, and potassic nitrate.

7. In acute cases, permanganate of potash, sulphate of ammonia, morphine as an antispasmodic. In chronic cases, remedies to affect the stomach, as common salt, hydrochloric acid, and gentian root.

8. Muriate tincture of iron with hygienic accessories.

CONCLUSIONS FROM LITERATURE.

From the foregoing review of the literature we may deduce the following conclusions:

1. There is a disease common among horses, cattle, and sheep in the semiarid region of the West, the animals affected showing these characteristics: Slow, staggering gait, rough coat, staring, vacant look, and emaciation. They have hallucinations, can not be led or backed, show more or less lack of muscular coordination, gradually lose flesh, and die. They show a hypersensitive condition of the nerves, so that if a horse affected with loco disease is suddenly startled he may rear and fall over backward. Cattle show less pronounced symptoms, but in general are affected like the horses. The characteristic of a locoed steer is the shaking head, together with the other nervous phenomena. To these symptoms may be added some others upon which there is no general agreement.

2. The cause of this disease is quite uniformly ascribed by the stockmen to plants known by them as loco plants, of which the principal ones are *Astragalus mollissimus* and *Aragallus lamberti*. Similar properties are ascribed to other closely allied species in Montana, Wyoming, Arizona, and California.

3. Scientific investigations of the subject have led to very contradictory results.

It will be noticed from the review of the literature that in the chemical and pharmacological examination Prescott got no positive results. The same is true of the experiments made by Gee. Kennedy found no poisonous principle and fed the loco to a dog with no results. Day got from the extract fed to cats definite loco symptoms, and similar results from her experiment with a jack rabbit. The work of Power and Cambier led to only negative results. Sayre made numerous experiments on himself and animals, and has reached the general conclusion that the weed possesses no poison. It will be seen that the only positive proof of the poisonous character of the plant was obtained by Doctor Day. The preponderance of laboratory tests made up to the time that the Bureau of Plant Industry undertook its investigations was, therefore, against the poisonous character of the plant.

The results of the study of locoed cattle, horses, and sheep in the field are no more conclusive. The reports of post-mortems show few lesions common to all cases, or even to any considerable number of them. There is a fairly general agreement as to some abnormal

condition of the brain and the nervous system, but so far as the other organs of the body are concerned, the reports do not agree with each other. There seems to be a general feeling of skepticism among those who have seen cases in the field as to the actual poisonous properties of the plants. The following have been suggested as the possible causes of the disease:

1. Starvation.
2. Irritation of the stomach by the hairs of the leaves.
3. Penetration of the stomach by the sharp hooks of the seed pods.
4. The loco absorbs the juices of the stomach, collects as a dry mass, causes pressure upon the circulation, and finally death.
5. The formation of balls in the stomach from sand taken in when the grass is short (bezoars), and the consequent irritation and inflammation due to the presence of this foreign substance.
6. Impaction of the intestines by twigs, etc.
7. Fermentation of the materials in the stomach.
8. Tapeworms.
9. Other parasitic worms.
10. Eggs or bots.
11. Trypanosomes.
12. Some poisonous principle in the plants.

To these possible causes might be added some suggestions made by stockmen which have little foundation. It is generally known that the loco plants are attacked by a considerable number of insect enemies, of which more will be said later. Among them are certain insects whose larvæ live in the roots and stems of the plants and have been noticed for a great many years by the stockmen. Many of the stockmen consider that these "worms," as they call them, are connected directly or indirectly with the loco disease. Some of them state that the eggs of the worms are taken into the body of the animal, hatch out there, and live in the alimentary canal; evidently confounding the ordinary parasitic worms of animals with these insect larvæ. C. D. Steele, in Farm and Ranch, in 1901, suggests that these "worms" consume the food in the stomach and thus produce starvation. One correspondent of our office has elaborated an interesting theory to this effect: That the cattle and horses eat the loco plants upon which are the worms, as he calls them, and the eggs of the worms. These eggs hatch out in the stomach of the locoed animal and crave loco for their own food, and it is to supply food to satisfy this craving of the worms that the horse or the steer frantically seeks loco.

It will be remembered that Sayre in his 1904 paper broaches three distinct theories: (1) Irritation by hairs; (2) disturbance of digestion, such as might have been caused by any food in the weakened condition of the animals in the spring; and (3) a poison developed in the process of digestion.

Marshall's investigations led him to conclude that the loco plant was not the direct cause of the disease and that many cases of so-

called loco disease were really caused by animal parasites. This seemed particularly probable in the case of sheep, which all through our western region are infested with *Œstrus ovis* and with *Thysanosoma actinioides*, as well as certain other animal parasites.

It will be seen that the loco problem up to the time when the review of this literature closed was an open one, with the presumption in favor of the nonpoisonous character of the plant, and in taking up the investigation of this subject it seemed necessary as the first step to determine positively whether the loco plants were really the cause of the so-called loco disease.

PLANTS KNOWN AS LOCO PLANTS.

A large number of plants have been known as loco plants. The following list is taken from the literature on the subject. It is to be presumed that there have been some errors in determination, but the length of the list shows that loco is a term which has been applied quite widely. By general agreement, however, the term, outside of California, New Mexico, and Arizona, is now rather generally confined to the two species, *Aragallus lamberti* and *Astragalus mollissimus*. In some localities the term "loco" is confined to *Astragalus mollissimus*, but this is generally in places where *Aragallus lamberti* is comparatively rare.

LIST OF SPECIES.

Amarantus albus.
Astragalus bigelovii Gray.
Astragalus crotalaria.
(=*A. oocarpus* Gray.)
Astragalus dorycnioides.
(=*A. succumbens* Dougl.)
Astragalus hornii, A. Gray.
Astragalus lotiflorus Hook.
Astragalus lentiginosus Dougl.
Astragalus menziesii Gray.
Astragalus mollissimus Torr.
Astragalus mortoni Nutt.
Astragalus palousensis Piper.
Astragalus spaldingii Gray.
Astragalus tridactylicus A. Gray.
Aragallus lamberti (Pursh.) Greene.
Aragallus sericeus (Nutt.) Greene.
Aragallus spicatus (Hook.) Rydb.
Argemone mexicana L.
Cannabis sativa L.
Crotalaria.
Cystium diphysum (A. Gray) Rydb.
Datura stramonium L.
Diholcos bisulcatus (Hook.) Rydb.
Diholcos haydenianus (A. Gray) Rydb.
Fritillaria pudica Spreng.
Lathyrus polymorphus Nutt.
(=*L. incanus.*)
Leucocrinum montanum Nutt.
Malvastrum coccineum (Pursh.) Gray.
Oxybaphrus.
Oxytropis lagopus Nutt.
(=*Aragallus lagopus* Nutt.)
Physostigma venosum.
Psoralea cuspidata Pursh.
Rhamnus lanceolata Pursh.
Sophora sericea Nutt.
Stipa viridula Triv.
Zygadenus elegans Pursh.
(=*Anticlea elegans* (Pursh.) Rydb.

DESCRIPTION OF ARAGALLUS LAMBERTI.

Aragallus lamberti (Pl. I) is a perennial growing from a root which may extend 2 or 3 feet or more into the ground. It is acaulescent and the leaves rise to a height of a foot or more. The general habit of the plant is of erectness. The leaflets are oblong, lanceolate, or linear, and are covered with a variable amount of silky hairs. In some varieties this pubescence is quite dense. The flower scapes are longer than the leaves and bear spikes which are either densely or sparsely flowered. The flowers are large and variable in color; the more common color of the plants on the plains is white, but they may be distinctly purple. The variations are from white, through a light purple and lilac, to a distinct purple. In some cases the corolla

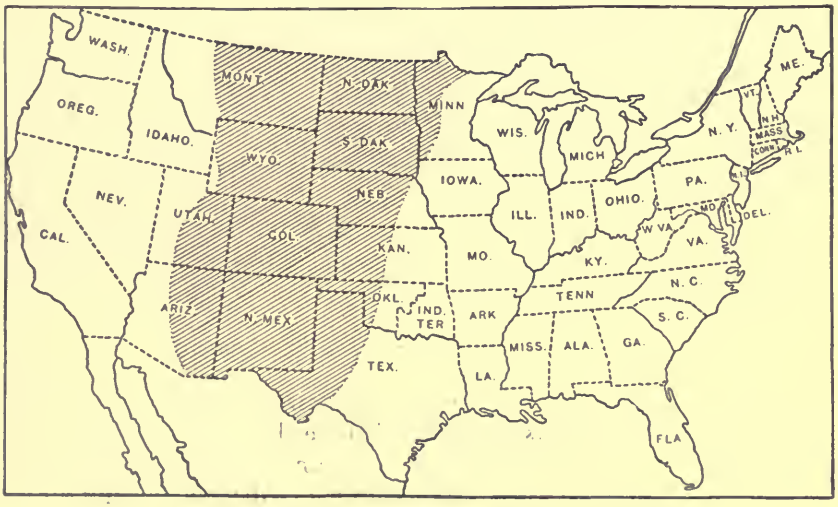


FIG. 1.—Distribution of *Aragallus lamberti* in the United States.

is white and the calyx red. In the mountain varieties there is the same variability in color, but the darker ones are more common, the predominating colors being deep violets and purples. The white varieties are commonly found in woods and near streams.

The plants are strikingly beautiful, and grow so abundantly that when in blossom on the plains large areas are as white as a field covered with snow, while in the mountains, although less abundant, the patches of several acres of bright purple and violet flowers are extremely attractive. The pods of the *Aragallus lamberti* are rather long, pubescent, and indistinctly two-celled. It grows most abundantly on the low hills of the plains, and in the pastures at the base of the mountains up to a height of perhaps 9,000 feet. It prefers a sandy soil.

Aragallus lamberti has an extremely wide range, as may be seen from figure 1. It is found from Alaska on the north down through

the Dakotas and as far east as central Minnesota; in Montana, Wyoming, western Nebraska and Kansas, eastern Colorado, Oklahoma, western Texas, New Mexico, and Arizona. In all these localities more or less damage has been reported, but it is in Wyoming, Colorado, and Arizona that the most trouble has occurred. It is abundant in the eastern foothills in Colorado, and on many of the mountain ranges horses are no longer turned out. It is especially abundant in parts of Elbert, Lincoln, and Cheyenne counties in eastern Colorado. In Arizona there is a large amount of this plant about the base of the San Francisco Mountains. It grows more abundantly east of the Continental Divide, but is by no means confined to this region. Considerable patches of it are found on the western slope in Colorado. In this region it has so far done very little damage, and most of the stockmen do not know that it occurs in that region at all.

The plant belongs to the semiarid region. It is not, however, entirely confined to dry soils and sterile regions. In the Black Hills of South Dakota it occurs in the forests and in soil which, during a part of the year at least, is full of moisture. The pubescence is much more marked in the dry regions. *Aragallus lamberti* is popularly known as "rattleweed" or "white loco."

The species *spicatus* (Hook) Rydb., *albiflorus* Nelson, and *sericeus* Gray are considered by Prof. C. F. Wheeler, who has determined our plants, as identical with *lamberti*.

DESCRIPTION OF ASTRAGALUS MOLLISSIMUS.

Astragalus mollissimus (Pl. II) is a perennial growing from a long root like that of *Aragallus lamberti*. Unlike the latter, it has distinct stems in the older plants, although the young plants appear acaulescent. The plant is inclined to be decumbent, although young plants are sometimes quite erect. In this habit it differs markedly from *Aragallus lamberti*. Most of the plants are comparatively small, living apparently not more than two or three years. Under favorable circumstances, however, they may grow into large bushy structures, perhaps a foot high and from 1 to 2 feet in diameter. The leaflets are broadly ovate or elliptical, and densely pubescent. This pubescence is very much greater than in *Aragallus lamberti*. The flower scapes do not ordinarily much exceed in length the leaves, and bear rather dense spikes of deep violet or purple flowers. The flowers are much smaller than those of *Aragallus lamberti* and less showy. The pods are thicker than those of *Aragallus lamberti*, smooth, and distinctly two-celled.

Plate II, figure 1, shows the appearance of the younger plants and the characteristic appearance of the leaves, flowers, and fruit, while figure 2 of that plate shows the general appearance of the older

Fig. 1.—Plant in flower.

Fig. 2.—Plant in fruit.

WHITE LOCO, OR RATTLE WEED (ARAGALLUS LAMBERTI).

Fig. 1.—Flower and fruit.

Fig. 2.—Habit of plant.

PURPLE OR WOOLLY LOCO (ASTRAGALUS MOLLISSIMUS).

plants, in which the decumbent character is more pronounced. It does not grow in as great abundance as the rattleweed, although occasionally a few acres may be pretty well covered. It grows best on an adobe soil, and where the two species—*Aragallus lamberti* and *Astragalus mollissimus*—grow near together, *Astragalus mollissimus* occupies the depressions and *Aragallus lamberti* is found on the hills.

Its range (see fig. 2) is not so wide as that of *Aragallus lamberti*. It occurs in Wyoming, Nebraska, Kansas, Colorado, Oklahoma, Texas, New Mexico, and Arizona. In the eastern part of the plains region of Colorado and in western Kansas and Nebraska *Astragalus mollissimus* is very abundant, while *Aragallus lamberti* is comparatively rare. The same is true of the Panhandle in Texas. In parts of New

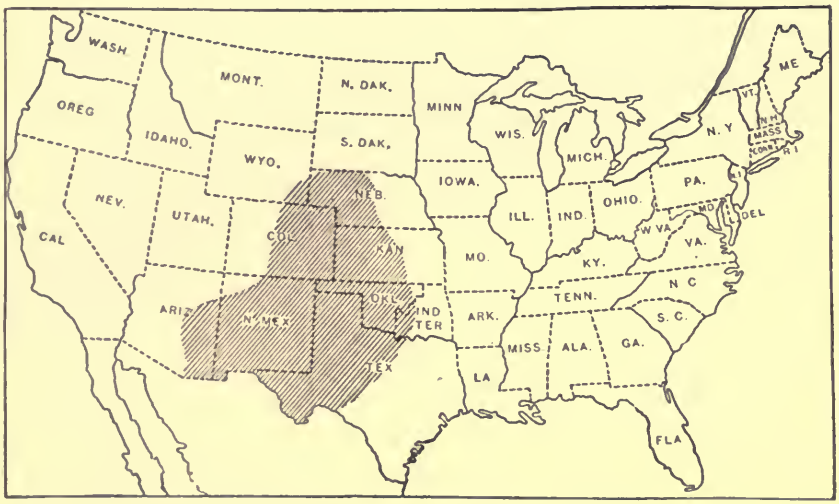


FIG. 2.—Distribution of *Astragalus mollissimus* in the United States.

Mexico it grows very luxuriantly. This is particularly true in some portions of the Estancia Valley and in the regions about Santa Rosa. It is found in less abundance in Arizona, and apparently in that Territory does very little harm. The most harmful of the loco plants in Arizona appear to be entirely distinct from the two species under discussion.

Astragalus mollissimus is popularly known as "purple loco," "woolly loco," or "Texas loco." Sometimes it is spoken of by the ranchmen as "the loco."

DISPERSAL OF ARAGALLUS LAMBERTI AND ASTRAGALUS MOLLISSIMUS.

When *Aragallus lamberti* ripens, the pods open while still on the flower scapes and the seed is scattered in the immediate neighborhood of the plant. The pods of *Astragalus mollissimus* are heavier

and may lie upon the ground, but because of their weight are not moved to any extent by the winds. Neither of these plants breaks off and becomes scattered in tumbleweed fashion. It follows that in the case of both of these species most of the new plants spring up in the immediate neighborhood of the parent plant, and the dispersal of the plants is a comparatively slow matter. It should not be assumed that the wind has no influence in scattering the seeds, for in a country of violent wind, seed, like everything else that is loose, will be carried about more or less. This is shown in the fact that *Astragalus mollissimus* is frequently abundant in and near wagon roads, doubtless because the moving seeds have been arrested in the depressions. Loco is said to be especially abundant near old sheep trails. This may be partly because of the seeds carried in the droppings of the sheep and partly because of the arrest of the moving seeds by the depressions and the planting of these seeds by the feet of the sheep.

It is said by some (Blankinship, 1903) that the bison were instrumental in the distribution of the plants either through their droppings or because of their habits of wallowing, by reason of which they may have carried the seed to great distances. These statements in regard to the distribution by sheep and bison, however, are entirely theoretical, for no exact observations have been made.

RELATIONS OF LOCO PLANTS TO FERTILE SOIL.

Incidentally it may be remarked that the loco weeds, like other leguminous plants, have root tubercles, and presumably are efficacious in adding nitrogen to the soil content. Mr. W. S. Pershing, of Limon, Colo., states that he has noticed that he has had especially good crops when he has used land on which loco has been growing. It seems very possible that while loco is a curse to the stockmen it may be of some benefit to the farmer.

EXPERIMENTAL WORK LIMITED TO TWO PLANTS.

The experimental work on which this paper was based was limited to the two species *Astragalus mollissimus* and *Aragallus lamberti*. There is reason to believe, however, that a considerable number of related plants may possess the same properties.

Horses in Arizona and New Mexico die with the typical symptoms of loco poisoning, and post-mortem examinations show lesions similar to those found in the victims of *Astragalus mollissimus* or *Aragallus lamberti*, but the loco plants are different species from those found farther north. While there is little reason to doubt that these plants possess the same poisonous principle and produce the same result, experimental work has not been undertaken to demonstrate these facts.

Through many parts of the West horses are said to become "saged" and to have many of the symptoms of loco poisoning. This has been noted by Mayo. The author has seen some cases of so-called saged horses, but there was no means of proving that they had not been eating loco plants. The testimony of stockmen who have what seems to them clear evidence of the production of these symptoms by the sages is not to be lightly set aside. It is hoped that it may be possible to do some convincing experimental work on these plants.

Reference should be made, in passing, to the poisonous effects of *Swainsona galegifolia*, known as the Darling pea or indigo plant, and other species of *Swainsona* which are said to produce in Australia symptoms like those caused by the American loco plants. MacÓwan considers the "nenta" of the Cape as produced in a similar way.

PART II.—EXPERIMENTAL WORK.

THE PROBLEM TO BE SOLVED.

It will be seen from the foregoing that when, at the earnest and persistent solicitation of the stockmen, it was decided by the Department of Agriculture to make a thorough study of the subject, there was very little definite knowledge to start upon. In spite of the fact that the subject had been under investigation for a third of a century, there was no consensus of opinion even in regard to the poisonous or nonpoisonous character of the plants themselves. The stockmen with very few exceptions were convinced that the plants were the cause of the disease. On the other hand, laboratory investigations were contradictory and the investigations in the field were not conclusive. The problem, as presented to the Department then, involved:

1. The definite determination of the poisonous or nonpoisonous character of the loco plants. This included (*a*) field experiments in feeding animals under normal conditions, with proper controls, to find out whether the disease could be produced by the loco plants, and (*b*) a pharmacological examination of the plants to determine whether a poisonous principle could be extracted, and if it could be extracted to determine its properties. The pharmacological work was entirely in the hands of Dr. Albert C. Crawford, who has made an independent report of his investigations.[a]

2. A careful examination of locoed animals, with numerous postmortems to determine the pathological lesions, with the end in view of making an accurate and fairly complete diagnosis of the disease from the pathological side.

3. An attempt to find some remedy for the trouble. This branch of the subject presented two aspects: (*a*) The suggestion of measures to eradicate the plant or to reduce its numbers, if it was found to be the cause of the disease; (*b*) the suggestion of remedies which could be given to the animals either for a cure or for lessening the effects of the disease.

It was evident that the investigation would have to be equipped in a very broad way. While the study was primarily of the loco

[a] Bulletin 129, Bureau of Plant Industry.

plants, it was necessary to be provided with means of making post-mortems, giving special attention to the presence of animal parasites; pathological tissues must also be collected and examined, the blood must be studied, and an equipment for the cultivation of pathogenic bacteria must be on hand.

PLAN OF WORK.

To carry out the first point in the investigation, it was determined to secure the use of land somewhere in the loco area, and fence in one piece covered with loco thickly enough so that the animals in the pasture would be compelled to eat loco, but with grass enough so that there would be no question of starvation. Another piece of ground, as nearly like the first as possible, but free from loco, was to be used as a control pasture. In addition, animals should be confined in the corrals and fed on cut loco, cut loco and hay, etc. It would be necessary also to confine certain groups of animals to definite loco species, and thus determine the differences, if any, in their poisonous properties. Incidentally, it was desired to travel through the loco country and collect facts in regard to the losses from loco, the loco conditions in different places, and the distribution of the supposed poisonous plants.

LOCATION OF EXPERIMENT.

As Colorado has perhaps suffered more losses from loco than any other region it was determined to locate the experiment in that State. A cooperative agreement was entered into with the Colorado Agricultural Experiment Station by which the station agreed to furnish, in aid of the work, the stock to be experimented upon and the services of a veterinarian for consultation when called upon. After some time spent by Doctor True and the author in examining different areas of the State where loco was doing most harm, it was decided to locate a temporary station at Hugo, in Lincoln County. The choice of this location was determined, in part, by the fact that no part of the West has suffered more from loco than this section of Colorado, and in part because of the active interest in the investigation manifested by the stockmen of that neighborhood.

In this connection the author makes grateful acknowledgment of the courtesies extended and valuable assistance rendered by many persons, too numerous to mention by name, in the course of the investigations. The stockmen not only gave freely of their time in showing local conditions, but were always ready to furnish animals for autopsy and to assist in their examination. The county board of Lincoln County made liberal appropriations for the experiment.

Special acknowledgment, too, should be made of the assistance very freely given by the railroad officials in the territory visited; without this help it would have been impossible to handle the work with the funds at our disposal.

PRELIMINARY WORK.

During a preliminary trip through the State a considerable number of locoed animals were seen. The picture in the text of case 513 (fig. 3), a stunted colt seen near Wray, is typical of the locoed horses observed on this trip. In spite of many cases, where there was an abundance of feed, the conclusion was reached that in the great majority of cases starvation was the principal if not the only factor in the so-called loco disease. Prof. W. L. Carlyle, of the Agricultural College, accompanied us in our examination of the neighborhood of Hugo, and agreed with us that an abundance of good feed would greatly reduce the number of cases and perhaps eliminate the problem.

FIG. 3. Case 513. A locoed colt, stunted in its growth by loco poisoning.

An old ranch house with its corrals was secured as laboratory headquarters for the work. A piece of ground of something over 200 acres, where the *Aragallus lamberti* was especially thick, was prepared as a loco pasture and was so fenced that the animals should always have access to running water. Over the whole of this 200-acre pasture the *Aragallus lamberti* was distributed in very great abundance. It is doubtful if there was a square yard of the pasture which did not have one or more of the plants. It was also very nearly a field of *Aragallus lamberti* simply. There were in the depressions small patches of *Astragalus mollissimus,* but during the progress of the experiment the animals were watched carefully, and there is reason to think that none of them ate this plant in this pasture.

Another piece of ground near by was arranged for a control pasture. This piece of land had a comparatively small amount of loco upon it. A force was set at work to clear out this pasture so that it would be to all intents and purposes a loco-free piece of ground. During the summer men were sent over it two or three times in addi-

tion, in order to kill out the seedlings as they came up later in the season. Thus in this pasture we had a piece of ground very nearly like the loco pasture but without the loco plants. Inasmuch, however, as the loco-free pasture was somewhat lower, it is a fact that the grass was rather better than in the loco pasture. However, there was an abundance of grass in the loco pasture, so that we consider that the starvation element was entirely eliminated.

WORK OF THE FIRST SEASON.

Twelve steers and fifteen horses were received from the agricultural experiment station for experimental purposes. Part of these arrived at the end of April, 1905, and part the first week in May. By the end of the first week in May the experiment was fairly started. The animals were given individual brands and numbered, so that the notes of each animal could be kept under its own number. Five of the cattle, Nos. 1, 2, 4, 5, and 6, and four of the horses, Nos. 13, 16, 22, and 23, were put in the loco-free pasture and kept there through the season as controls. In selecting these controls the animals were taken by a chance selection in order that the loco animals should be just as good as the controls but no better. The controls had an uneventful history. All kept well and flourished throughout the summer, and came out in the fall in good condition.

Of the remaining animals part were put in the loco-free pasture to be drawn upon for corral experiments, and part were placed in the loco pasture. In order to induce the loco animals to eat a large amount of the weed, it was found expedient after the last of May to bring them into the corrals at night and keep them in until rather late the next morning. By this treatment they went to the pastures in the morning very hungry; and as hungry animals—and this is especially true of cattle—are apt to eat the most prominent plants, they would for an hour or two eat loco almost exclusively. After satisfying their first hunger they would commence to eat grass. It was found that they ate much less loco when kept in the pasture nights as well as days.

Astragalus mollissimus did not occur in sufficient amount near Hugo so that a pasture could be arranged where stock could be fed, and we found it necessary for experiments on this species to cut the loco and feed the animals in the corrals. A little later a considerable piece of ground was found on the Van Antwerp ranch, about 10 miles south of Hugo, where the *Astragalus mollissimus* was particularly luxuriant. This piece of ground was loaned for experimental purposes by Mr. Laurie, and was fenced in as a pasture. Two horses and two steers were placed in it on July 13. The pasture was visited every other day and the animals were watched to see what they were

eating. It was necessary to construct a lane from the pasture to a well so that they could get water, and in this lane there was a considerable amount of *Aragallus lamberti*. The animals ate this plant, but there is no evidence that they ate any of the *Astragalus mollissimus*. It was hoped that as the grass gradually became shorter they would be forced into eating the weed, but to our surprise within two or three weeks nearly all the *Astragalus mollissimus* was dead, having succumbed to insect enemies. On August 25 it was decided to take the animals out and abandon the pasture, as there was not enough of the loco left to form any prominent part of their food. There was no evidence that the animals in this pasture had eaten any of the loco even when it was most abundant, so the pasture experiment upon *Astragalus mollissimus* must be considered as a failure.

All the animals, when received in the spring, with the exception of one horse which died soon after its arrival in Hugo, were in apparently healthy condition, although rough and poor, as they had just come off the range and suffered more or less from short winter feed. As the result of good pasture, all commenced immediately to improve. The steers in the loco pasture ate *Aragallus lamberti* freely, and while we at first imagined that they were affected by it, it soon became evident that they were thriving. Their coats became smooth, they gained in flesh, and seemed to give evidence that the loco diet was an excellent one. The earlier autopsies, too, instead of showing the presence of intestinal parasites, as had been expected, apparently showed that loco animals had fewer internal parasites than would be expected in normal animals. Our skepticism in regard to the poisonous effect of loco was confirmed, and it appeared probable that we should prove that loco was a myth, or, at least, a misconception, and that the cause of the disease must be sought in some other direction. As the season progressed, however, occasion was found for a change of opinion, as will be seen after the description and detailed discussion of the cases.

The experiment was carried on through the season with no unexpected difficulties of a serious nature, with the exception of the appearance of glanders in the loco pasture. Suddenly one of the best of the horses developed this disease in an acute form and died after a short illness. This case was followed by another, which also died. Fortunately the disposition of the animals just at that time was such that there was reason to think that only one other horse had been exposed. This horse was isolated for a time, care was taken to give the pasture a chance for disinfection, and the experiment was resumed with no further untoward result. It is to be presumed that this case resulted from infection received before the animals arrived in Hugo.

A brief history is given in the succeeding pages of some of the more interesting cases. In these statements the results of the autopsies are not mentioned, as they are discussed in some detail later (see p. 95).

EXPERIMENTS WITH CATTLE.

Case 7.—This steer was pastured on *Aragallus lamberti* during the first part of the season. Later it was taken into the corral and fed exclusively on cut *Aragallus lamberti*. This was eaten very freely for a short time, when the animal showed distaste for it, and the experiment was tried of feeding *Astragalus mollissimus* in the corral. This the steer utterly refused to eat even when starved to it. When on occasional days the animal was turned out into the pasture it would eat grass and *Aragallus lamberti*. In order that it might not starve to death, it was afterwards turned into the *Aragallus lamberti* pasture, remaining in the pasture until October. In the middle of October it suddenly began to show weakness when walking, this being especially noticeable in its hind legs, and within two weeks of the time when the first symptoms were noticed it was found down in the pasture, and was killed and autopsied. This was a clear case of poisoning from the eating of *Aragallus lamberti*.

Case 8.—This steer was pastured on *Aragallus lamberti* from the first of the season of 1905, and no effects were noticed until the latter part of July, when it developed a solitary habit, and early in August was found to be very weak, stepping high and straddling with what are considered the peculiar loco motions. Plate III, figures 4 and 5, show this peculiarity of walking quite clearly. On August 27 the animal was down and unable to stand. When assisted to get upon its feet it would balance itself and fall over. Figure 6 of Plate III shows the animal in the act of attempting to stand after being assisted. At this time it would eat nothing, but would still drink a little water. This weakness came on very suddenly, for on August 26 it was driven to the pasture and came in in fairly good condition. The steer was killed on October 28 and the autopsy made.

Case 9.—This steer was fed on *Aragallus lamberti* from the beginning of the season. A note was made the latter part of May showing that the animal was in especially good condition at that time. At the end of June it was taken into the corral and fed cut *Astragalus mollissimus*. It ate freely at first but afterwards refused the plant, and an attempt was made to tempt it by mixing grain with the loco. It ate this for a little time, but soon would not eat the loco even with the chop, and because of the fear of starvation it was turned into the *Aragallus lamberti* pasture on July 21. At first the steer appeared to pick up and presented a very much better appearance. On August 30 it was taken into the corral again and fed with a mixture of *Astragalus mollissimus* and hay. It would eat the hay, but did not care for the loco. It was kept in the corral until September 17, during all this time eating the hay, but refusing the loco. As it was found impossible to make the animal eat the loco, the experiment of feeding

in the corral was abandoned, and it was turned into the loco pasture, where it commenced to eat *Aragallus lamberti* again. On October 14 it was noticed that the steer was very weak and would fall when driven rapidly. On October 27 it seemed best to kill the animal and make an autopsy.

Case 10.—This case was one of particular interest, as shown in the history of this and the succeeding years. The steer was put in the *Aragallus lamberti* pasture at the beginning of the season and on July 15 was taken to the Van Antwerp pasture with the hope of getting him to eat *Astragalus mollissimus*. This pasture at that time was filled with purple loco, and there was a considerable amount of *Aragallus lamberti* in the lane leading from the pasture to the corrals. There is no evidence that the steer ate any of the *Astragalus mollissimus*, but *Aragallus lamberti* was eaten by some of the animals and doubtless it had its share. Because of the destruction of the *Astragalus mollissimus*, on August 25 it was returned to the *Aragallus lamberti* pasture. The animal ate more or less of the *Aragallus lamberti* during the season, generally less, and as the season went on it ate less than in the earlier part of the year. On September 19 it was taken into the corrals and fed upon *Astragalus mollissimus* and hay. This diet was fed until October 8, but the steer continuously refused the *Astragalus mollissimus*. It was found impossible to force the loco diet and the animal was turned back into the *Aragallus lamberti* pasture on September 24. During the rest of the season it ate very little of the loco and at the end of the season was in good condition. This animal, it will be noticed, apparently ate the loco mainly because it was green and fresh and did not at any time acquire an appetite that would lead it to eat the plant in preference to grass.

Case 11.—This steer was placed in the *Aragallus lamberti* pasture at the opening of the season and ate loco from the start. No noticeable effect appeared until October. On the 16th of this month it fell when it was being driven into the pasture, and fell again at night as it was being brought in, showing that it had become extremely weak. At this time it was poor but by no means in a starving condition. It grew steadily worse, and on October 26 was found down and unable to rise. Its eyes were staring, its head shaking, and its coat rough. It was killed and an autopsy made October 27.

Case 12.—This was a black steer which was placed in the *Aragallus lamberti* pasture at the beginning of the season. This and No. 8 ate loco more freely than the other steers, and it was noticed that they were physicked more than was the case with the other animals. During the first part of the season both appeared to thrive upon the *Aragallus lamberti*. On May 30 this animal was taken into the corral and fed *Astragalus mollissimus* exclusively. At first it ate freely,

but later ate very little and finally refused absolutely to touch it and became very poor. On June 7 *Aragallus lamberti* was placed before the steer and it immediately commenced to eat it. Then the experiment was tried of mixing *Astragalus mollissimus* and *Aragallus lamberti*, and it was found that the animal would pick out the *Aragallus lamberti* and eat it but would leave all the *Astragalus mollissimus*. As it was evident that the animal would not acquire a taste for *Astragalus mollissimus* it was put on a diet of *Aragallus lamberti* in the corral. It was fed this exclusively from July 3 until July 24, but during this period was driven into the pasture on Sundays. In the pasture also it was noticed that it ate *Aragallus lamberti* very freely. The *Aragallus lamberti* was supplied to it in the corral in abundance and it ate very readily, but became steadily poorer, its coat becoming rough. During the last week of the corral treatment chop was mixed with the loco in order that it might not be without nutritive food, but on July 24 it was so much reduced that there seemed to be danger of starvation. Accordingly it was turned out into the pasture in the hope that it might pick up. Instead of picking up, however, it grew worse and became so weak that on August 1 it was found unwise to try to get it into the corrals. It steadily grew poorer and an autopsy was made on August 5.

EXPERIMENTS WITH HORSES.

Case 17.—This animal was an iron-gray horse, one of the best appearing animals of the lot received in 1905. Full of life and with a good gait, it was remarked by horsemen who examined the animals that he was an exceptionally good-looking animal. He was placed in the *Aragallus lamberti* pasture at the beginning of the season and presumably ate no loco at that time. On May 20 the horse was taken into the corral and fed upon cut *Aragallus lamberti*. He did not eat it readily at first, but afterwards ate it fairly well. On May 28 the horse was showing a very decided loss of flesh and his excess of life had disappeared. He had become a sleepy and dull horse. While he was being fed in the corral on June 6 he managed to get hold of a box of *Astragalus mollissimus* roots and devoured them very greedily. It was noticed, too, that when a wagon loaded with *Astragalus mollissimus* was driven into the corral he tried to get the loco from the sacks, although there was at the same time uneaten *Aragallus lamberti* in the corral. It was found at this time that he would make his way past numerous obstacles to get at bags of roots of *Astragalus mollissimus*. Although the way was barred, he would find the sacks and steal them. Our first impression was that he had a real passion for this loco. On June 8 the experiment was tried of mixing *Astragalus mollissimus* and *Aragallus lamberti*, when it was

found that he very carefully picked out the *mollissimus* and left the *lamberti*. He was then taken out to the pasture where both weeds were growing to see whether he would manifest the same choice, but there he devoted himself to grass, ignoring both kinds of loco. Later on, in thinking over the matter, the conclusion was reached that while he might have had some desire for the *Astragalus mollissimus*, the stealing of the roots and the cut loco might be explained simply as a desire to steal rather then a preference for the loco itself, because it would seem that if he really was anxious to get the loco he would have picked it out in the field, where there was an abundance of it.

The horse had become very poor at this time—July 18—and as it was deemed unwise to leave him in the corral he was put in the pasture and soon showed marked improvement. Up to this time there was no reason to think that he had eaten *Aragallus lamberti* in the field, but from now on he ate it quite freely. From August 2 to August 25 he was kept in the hospital pasture for fear of infection from glanders. Then he was returned to the *Aragallus lamberti* pasture and soon developed a solitary habit, grew exceedingly poor, and on September 20 was found in a dying condition.

Case 18.—This animal was kept in the *Aragallus lamberti* pasture from the beginning of the season until May 6, when it was taken into the corral and fed upon cut *Aragallus lamberti*. She ate it very freely almost from the start. From May 9 to May 21 she was kept in the pasture, and during this time apparently ate very little *Aragallus lamberti*. On the latter date she was again taken to the corral and fed with the cut weed. A week later, as she showed distinct evidence of having become poorer, and had a very sleepy appearance, she was put in the loco field for two or three days, where she ate *Aragallus lamberti* very freely. Then she was again taken into the corral and fed exclusively on *Aragallus lamberti*, except as she was allowed the run of the pasture on Sundays. She showed continuous loss of flesh until July 1, when she died very suddenly. During this time she had shown no peculiar nervous symptoms, but had simply gradually wasted away. The result of the experiment seemed to indicate that there was a lack of nutritive material in the plant, and that death was not only the result of poisoning, but probably the result of starvation. Plate IV, figures 1 and 2, show the condition of the animal after it had become locoed.

Case 19.—This mare was kept in the loco-free pasture until August 18. At that time she was taken into the corral and fed on *Astragalus mollissimus* and hay. She ate very freely in the corral, ordinarily picking out the loco from the hay, but also eating fairly well of hay. Later in the experiment there was a period when she picked out the hay rather than the loco, but most of the time she seemed to prefer

Case 8, July 19, 1905. Just before the locoed condition was particularly evident.

Case 8, August 3, 1905. When the animal showed typical symptoms of loco poisoning, especially in its attitude.

Case 8, August 23, 1905. Emaciated condition of animal and typical loco attitude of lowered head and braced legs.

Case 8, August 23, 1905. Loco leaping unnecessarily high in going over a rut in the road.

Case 8, August 23, 1905. Loco lifting foot unnecessarily high in passing over a wire.

Case 8, August 27, 1905. Animal too weak to stand unaided.

Case 18, May 12, 1905. A mare weakened by loco poisoning.

Case 18, June 27, 1905. Advanced condition of loco poisoning.

Case 19, May 16, 1905. Horse before eating any of the loco weed.

Case 19, August 31, 1905. Animal eating loco at a time when it had lost some flesh, but was not in bad condition.

Case 19, October 15, 1905. Animal in a very much reduced and emaciated condition.

Case 19, October 26, 1905. Animal just before its death.

Case 524. Peculiar way in which a locoed horse uses its mouth in attempting to eat.

Case 533. How a locoed horse will rear when suddenly startled.

Case 525. Peculiar gait which a locoed horse exhibits.

Case 525. Locoed horse rearing when suddenly startled by a hat thrown out in front of it.

Case 529. A locoed Angora goat unable to get upon its feet, but otherwise fairly well.

Another attitude of Case 529.

the loco. The experiment was continued until October 15, with the exception of Sundays, when she was allowed to run in the pasture. During this time she lost flesh very decidedly. From October 15 to October 18 she was kept in the *Aragallus lamberti* pasture to see if the freedom of the pasture would not cause her to pick up somewhat in strength and in flesh. She was brought into the corral on the morning of October 18 very poor and lifeless, dragging her hind feet as she walked, the near foot being more affected apparently than the off foot. It was decided to give her hay with chop for a few days to see if she could not be brought out of the diseased condition. She refused to eat the chop and on October 21 would eat neither chop nor oats, but would eat hay. She remained in the corrals until October 26, when she died and the autopsy was made. The death in this case was at least partly caused by starvation as well as by the effect of the poison. Plate IV, figures 3 to 6, show the change in the condition of the animal.

Case 20.—This was a yearling mare which was placed in the *Aragallus lamberti* pasture on May 8. She was not observed to be eating any loco until the latter part of August. After that time she ate more or less *Aragallus lamberti*. We do not know that the mare ate any large amount at any time, but she grew poorer steadily and disappeared on September 21, and was found dead a day or two later. The animal was interesting in that the poison took effect in a comparatively short time and rather unexpectedly.

Case 24.—No. 24 was a 6-year-old horse, a good-looking animal. He moved with erect head and long step, and was marked as one of the better appearing horses in the experiment. He remained in the loco-free pasture until the end of May and then was fed in the corral upon cut *Astragalus mollissimus*. He ate it very freely, in fact would eat about all that was furnished. This diet was continued until June 11, when the horse was turned out for a day. When returned to the corral he took the loco again very readily, although he did not seem hungry. There was no evidence that the horse ate any loco at all while in the field. At first there seemed to be no effect from this feeding experiment. The animal did not lose flesh, retained its spirits, and showed no symptoms of unhealthy nervousness. After the middle of June, however, he gradually lost flesh and early in July he was so poor that it seemed likely that we might have a case of starvation, so he was turned into the pasture to pick up. The animal still seemed to have fairly good spirits, carrying its head high, but the coat was rough and the bones exceedingly prominent. In the pasture he ate the grass, not caring for the loco, and it was hoped he would gradually pick up and get in form for further experimentation. Somewhat to our surprise on July 8 the horse was found dead. He lay

under a barbed wire fence and it was evident had kicked about for a considerable time before death. His death could not have been entirely the result of weakness.

It may be mentioned as a feature of this case that during the latter part of the horse's stay in the corral tumors as large as a small fist, one or two at a time, would appear upon the groin. These appeared and disappeared in a day or two. None were noticeable at the time of death.

Case 26.—This horse was taken from the loco-free pasture on July 13 to the Van Antwerp pasture to experiment with *Astragalus mollissimus*. There is no evidence that the animal ate any of the *Astragalus mollissimus* in this pasture, nor does it seem probable that it ate the *Aragallus lamberti*.

Because of the death of the purple loco the horse was brought back and placed in the *Aragallus lamberti* pasture on August 25. It began to eat the loco within two weeks, and soon it and its companion horse developed the solitary habit. The horse ate the weed continuously until September 15, when it died somewhat suddenly. The animal before this had shown a peculiar straddling gait which was especially noticeable in its hind legs, but it did not seem to be particularly weak nor in a bad condition.

CASES OF CATTLE AND HORSES NOT SUBJECTS OF EXPERIMENT.

Besides work upon the station animals a considerable number of locoed cattle and horses were examined at ranches near Hugo and at other points in Colorado. In most cases autopsies were made. Some of the more interesting cases will be briefly mentioned below.

Case 501.—This was a cow belonging to Mr. Frank Ewing, of Hugo. When found the animal was too badly decayed for autopsy, but it was a particularly interesting case of the very pronounced swelling under the jaw, which is considered as one of the peculiar symptoms of loco poisoning. The tumor was filled with a clear serous fluid.

Case 503.—This was a 2-year-old steer belonging to Mr. William Hazel, of Hugo. This case is interesting as being a typical locoed range steer. The animal was found near a watering place about 2 miles from the loco station. It was down, but with head erect. Its eyes were sunken and staring, its coat rough and very poor. When startled it responded with peculiar nervous twitchings.

Case 519.—This was the first horse upon which an autopsy was made. It belonged to Mr. Charles Johnson, of Akron, Colo., and had been considered one of his best horses. The animal had been eating loco for two or three years. It was poor in flesh, with shaggy mane and tail, its coat was rough, the hair being off in patches, and it walked with a peculiar stiff, irregular motion of the legs, and had become absolutely worthless.

Case 524.—This was a colt belonging to Mr. Kendrick, of Seibert, Colo. The interest connected with this animal was largely in its peculiar way of eating. It had been taken into the corral to feed in order to get rid of the loco symptoms. It was in good flesh, but very nervous, constantly walking about the corral. Plate V, figure 1, shows the peculiar nibbling way of eating, a motion that is characteristic of locoed animals.

Case 525.—This was a horse belonging to Mr. John Lieber, of Hugo, and is referred to in this place because of the particularly good pictures (Pl. V, figs. 3 and 4) which were obtained of its attitudes, which show the peculiar gait of a locoed animal and the attitude which one is likely to assume when startled. The horse was very poor, being little but skin and bones, with rough coat and shaggy mane and tail. When walking over a railroad track it was noticed that its feet were lifted very high in order to clear the rails.

Case 533.—In this case, too, a particularly good picture (Pl. V, fig. 2) was obtained of the position assumed when startled. This horse was seen on a ranch north of Claremont, Colo.

Case 529.—This case was one of considerable interest, as being the only case of a locoed goat encountered during the season's work. The animal was an Angora goat belonging to Mr. Lon Foote, of Hugo. It was received at the experiment station on September 23, 1905, and at that time was unable to stand. The animal moved its legs spasmodically, and by great effort, with assistance, would get upon its feet, but would soon fall down, falling clear over, with its head prone upon the ground. It would eat grain very freely and would drink readily. The first impression on seeing it as it lay upon the ground was that it was in the agonies of death, because of the peculiar convulsive movements of its legs. The owner said that it had been in the corral since spring. During the winter it had eaten very freely of *Aragallus lamberti*, and its present condition was considered as entirely due to this food. The goat was kept at the loco station from September 23 to September 29, and during that time showed very little change in condition, except that it grew somewhat weaker. Within two or three days after arrival at the ranch the goat was unable to stand upon its feet at all, and could not even sit with the head in an erect position for any length of time. When put in a sitting position so that it could eat, the goat would do so for a little time, then with a peculiar jerky, convulsive movement the head would be thrown back bit by bit, finally falling over on the side, with the horns lying flat on the ground. As it seemed probable that nothing more could be gained by keeping it, the goat was killed and autopsied. Plate V, figures 5 and 6, show the characteristic attitudes assumed by the animal.

SUMMARY OF FIRST SEASON'S WORK.

The detailed discussion of the results of the work of 1905 will be taken up after the description of the cases of the second year. It may be well, however, to insert here the statement which was formulated at the end of the season as embodying the results so far obtained.

1. There is no longer any question of the poisonous effect of the loco weeds. The results of the feeding experiment at the ranch seem to prove conclusively that *Aragallus lamberti*, or rattleweed, when eaten for a prolonged period of time, has an effect of poisoning upon the nervous system, which leads to a lack of muscular coordination. The animal's nervous system becomes impaired to such an extent that the nutritive functions are interfered with and the victim perishes by starvation. The presence of ulcers in the fourth stomach of some of the steers may possibly be a characteristic lesion. The finding of a serous exudate in the spinal canal in certain of the autopsies would seem to indicate that this is another definite lesion produced by loco.

2. *Aragallus lamberti* will evidently poison both horses and cattle; presumably also it has the same effect upon sheep, although the season's experiments did not have enough to do with sheep to make this at all evident.

3. *Astragalus mollissimus* has the same general effect upon horses and sheep as *Aragallus lamberti*. They do not eat it as readily, but when eaten it has the same general effect.

4. Cattle can be poisoned by *Astragalus mollissimus*, though as a matter of fact they rarely eat it. It was shown quite clearly by the feeding experiments that it was very difficult to make cattle eat this weed. In the neighborhood of Hugo, Colo., loco poisoning may be considered as almost entirely due to *Aragallus lamberti*. It is noticed, too, that in parts of the State where *Astragalus mollissimus* is the common loco plant, like the region around Holyoke, locoed cattle are almost entirely unheard of. The same may be said of the Panhandle in Texas, where the common loco plant is *Astragalus mollissimus* and where locoed cattle are very unusual. It seems probable, then, that the generalization may be made that, while both these plants will produce poisonous effects upon both cattle and horses, it is very rare that cattle will eat *Astragalus mollissimus*, and that so far as the cattle industry is concerned the loss from this plant is probably exceedingly small.

In the case of horses it appears that while they eat *Astragalus mollissimus* more readily than do cattle, they are not likely to eat it unless forced by shortness of food, while both horses and cattle may contract the habit of eating *Aragallus lamberti* even when an abundance of food is present.

5. It has been argued by some that the so-called loco disease was simply the result of starvation, and that if animals had sufficient to eat there would be no trouble from loco. The feeding experiments seem to indicate, however, a specific poisonous effect of the weeds. The animals that were fed upon loco alone starved to death, but animals were also given abundance of other feed mixed with loco, and in these cases they also died, showing conclusively that loco kills not simply by a lack of nutrition, but because of a definite poisonous effect produced by the plant itself.

At the end of the season, about the middle of November, the surviving animals were taken to a ranch for the winter, where they were pastured and fed hay when necessary, but none of them had any loco. It was intended that they should have the same care that would ordinarily be given by the stockmen to animals that were kept under common range conditions.

WORK OF THE SECOND AND THIRD SEASONS.

The work of the first season, as has been indicated above, seemed to bring certain fairly definite results. The experiment, however, was on too small a scale, the number of animals was too small, and the general character of the experiment too circumscribed to permit one to speak at all dogmatically as to the deductions which should be made. The autopsies in many cases were performed too hastily for satisfactory results. The labor of conducting the routine work was greater than had been expected and taxed the capacity of the station force seriously. It was therefore necessary to repeat the work of the first season on a larger scale if possible, and thus confirm or modify the tentative conclusions which had been reached. The plan of the second season (1906) then was on the same general lines as that of the first season, but modified somewhat by the experience already undergone. For example, there seemed no longer any doubt of the poisonous nature of the loco weeds, so that it seemed unnecessary to carry any large number of control animals. The season's work as planned involved:

1. Pasture feeding on *Aragallus lamberti* as in the preceding season.
2. Corral feeding on both *Astragalus mollissimus* and *Aragallus lamberti* under various conditions.
3. Careful post-mortem examinations to determine the definite lesions characteristic of the disease, the work of the first season not being conclusive on this point.
4. The determinations of the effects of loco on sheep as well as on horses and cattle.
5. Experimentation with such remedial measures as were indicated by the conclusions already reached.

6. The extension of the knowledge of loco plants as much as possible.

The preceding work and the main work of the second year were with *Astragalus mollissimus* and *Aragallus lamberti* in a restricted area. Not only should more be known of the extent of the damage from these two species, but it was desirable to know to what extent, if any, other related plants are the cause of similar results. At the conclusion of the second season it appeared that the first four heads had been covered fairly well, while a fair beginning had been made with the last two, although the work was incomplete.

In addition to the work at Hugo, in which the Colorado Agricultural Experiment Station cooperated as in the preceding season, the Department carried on a station at Woodland Park, Colo. Woodland Park is near Pike's Peak, and the conditions are very different from those in the plains, although the most abundant loco plant in this region is considered by botanists to be specifically identical with the *Aragallus lamberti* of the plains. Another loco plant, *Astragalus nitidus*, is abundant in the pastures in this neighborhood.

In cooperation with the Nebraska experiment station, a feeding experiment with *Astragalus mollissimus* was also carried on at Imperial, in western Nebraska. In this region the only abundant species of loco is *Astragalus mollissimus*.

The feeding experiment during the second season was carried on in the same general way as during the preceding year. Of the cattle, Nos. 1, 30, 31, 43, 46, and 47, and of the horses Nos. 49, 51, 54, 55, 61, and 65 were placed in the loco-free pasture as controls and kept there throughout the entire season. All prospered and were in good condition at the end of the season. Of the others, some were pastured in the *Aragallus lamberti* pasture and some were fed *Aragallus lamberti* and hay in the corrals. Twenty-three head of cattle were subjected to the feeding experiments, and of these eight were dead at the end of the season and two were locoed, but recovered under treatment. The history of some of the more interesting cases follows. In these cases, as in those of 1905, the results of the autopsies are discussed later on in this paper.

EXPERIMENTS WITH CATTLE.

Case 2.—This was a steer which had been kept in the loco-free pasture during the entire season of 1905 and during the season of 1906 until May 9. It was one of the best appearing animals, a particularly good looking and high spirited steer. On the latter date it was placed in the corral and fed on a mixture of hay and fresh cut *Aragallus lamberti*. At first it refused to eat the loco plant, and when the latter was mixed with the hay would shake out the loco weed and

eat the hay, but after a few days in the corral it ate the loco with a fair degree of readiness. The steer was kept in the corral until August 19, except for an occasional day, when it was permitted to run out in the *Aragallus lamberti* pasture. On May 27, when it was run out in the pasture it was noticed that it would eat nothing but *Aragallus lamberti*, and for some time before this date in the corral it had eaten loco rather than hay.

The first positive symptoms from the eating of *Aragallus lamberti* were noted on July 19, when it fell as it was passing through a gate to go to water. From this time on it always showed more or less symptoms of being gate shy; that is, would stoop in passing through a gate as though endeavoring to get under a wire. It became hard to drive and was more and more stupid as time went on. This stupidity was especially marked because of the prior activity of the animal. When kept in the loco-free pasture it had been the source of a good deal of trouble, because it was inclined to break through the fences and, when through, was caught only with difficulty. During the first week in August the animal lost its appetite and showed great nervousness, its head shaking as though it had the palsy. Sometimes in passing through a gate it not only would crouch but would fall down. Plate VII, figure 1, shows the peculiar attitude which it assumed at such times. It became very much constipated, and on August 12, when driven out of the pasture, would continually stumble and fall. It suddenly grew worse, and on August 23 fell and was unable to get up again. It died on the 26th and was autopsied.

Case 3.—This was another steer remaining from the season of 1905. It was in the loco pasture during that season, but did not show any marked results of poisoning. In the season of 1906 it was placed in the *Aragallus lamberti* pasture in the spring and immediately commenced to eat the weed. It ate very freely and began early to show the effect of the poison. On July 3 it was noticed standing by itself in the pasture, and on July 9 its condition was so marked that it seemed desirable to take it to the corral and attempt remedial measures. The steer was accordingly fed hay and chop, part of the hay being alfalfa. It gradually grew worse, however, and on July 16 was found down; in the afternoon it was deemed best to kill it and make an autopsy. Plate VI, figure 1, shows the animal just before its death, and Plate VI, figure 2, shows the interior of the wall of the fourth stomach, with the ulcers which were present in considerable numbers.

Case 10.—This was also an animal which had been experimented upon during the preceding season and had shown only the general effect of what may be called moderate eating. It was placed in the *Aragallus lamberti* pasture in the beginning of the spring of 1906 and ate the weed with considerable freedom. It was noticed toward the

end of April that the animal was very thin, its coat rough, and that it walked with its head down in a spiritless way. This probably was due not so much to the loco feeding as to the short feeding during the winter, as it had been in the loco pasture only a short time. From this time it commenced to eat *Aragallus lamberti,* but not very freely. It then weighed 507 pounds; on May 7 its weight was 590 pounds, and its maximum weight during the summer was reached on September 7, when it weighed 840 pounds.

The history of this animal was interesting because, while during the two seasons it ate more or less of the loco, it never ate it in any very large amount. It could well be compared to the moderate drinker of alcoholic liquors, for it was not poisoned so as to show the effect of the weed in a very marked degree, but it was affected to the extent of not gaining as much as would naturally be expected. The curve of the weight (see fig. 4) shows this effect, for if this curve is

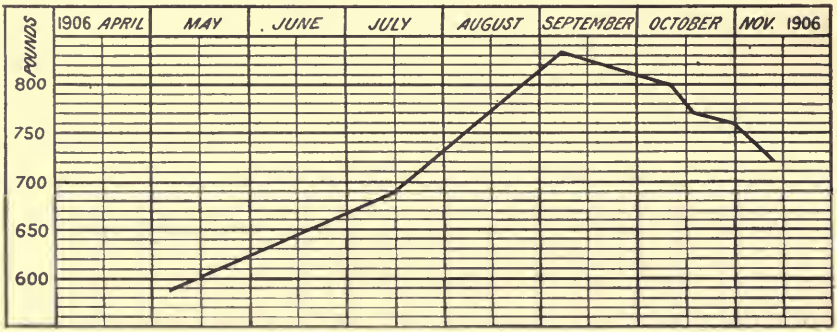


FIG. 4.—Curve of weight of steer No. 10, 1906.

compared with those of animals in good pasture it will be noticed that it is flatter, while the animals in good pasture gained with great rapidity until the end of the season. This was the only steer that refused to eat *Aragallus lamberti* in any large amount.

During the season of 1907 No. 10 was herded with the other experiment animals in the loco pasture and continued as in the preceding seasons to eat more or less of the *Aragallus lamberti.* At no time, however, did the steer eat enough to show marked effects from the poison. At the end of the season the gain in weight was once more much less than it should have been normally (see fig. 5), but this failure to increase in weight was the only evident effect of the loco poison. Case 10 is a good example of the possibilities of cattle eating loco season after season without showing serious effects from the poison.

Case 32.—This was an Aberdeen Angus cow carrying a registry tag. She was placed in the *Aragallus lamberti* pasture in April, 1906, and commenced immediately to eat the plant. She dropped a calf on May 6. She continued to eat *Aragallus lamberti,* and her

FIG. 1.—CASE 3. EFFECT OF LOCO POISONING, SHOWN IN EMACIATION AND DEJECTED ATTITUDE, JUST BEFORE DEATH OF ANIMAL.

FIG. 2.—INNER WALL OF FOURTH STOMACH OF CASE 3, SHOWING ULCERS UPON ITS SURFACE.

Case 2, July 25, 1906. Steer bending low to avoid an imaginary obstruction above it while passing through a gate.

Case 34. Another case similar to that in Fig. 1.

Case 67, May 1, 1906. A bright heifer calf shortly after birth.

Case 67, July 5, 1906. Calf shown in Fig. 3. Effects of loco which it had eaten in imitation of its mother.

Case 67, October 16, 1906. Calf with typical symptoms of loco. The long hair of the face is especially noticeable.

Case 67, October 19, 1906. Animal just before death.

weight on July 5 was only 850 pounds as compared with 1,025 pounds on May 3. Of course her weight would have been reduced, in any case, at the time of the birth of the calf, but, under normal conditions, being a large, strong animal, the weight should have been regained in a short time.

The effect of loco upon her coat was noticed on July 19, although the symptoms were not at that time very pronounced. They became

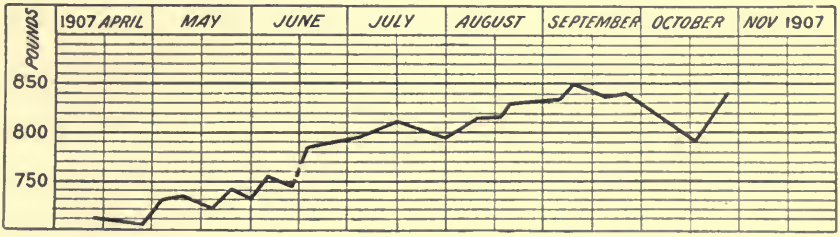


FIG. 5.—Curve of weight of steer No. 10, 1907.

more and more so, however, and on July 30 she had great difficulty in getting up after being down, and walked in the typical loco fashion. She died on August 26. The case was one of especial interest because she commenced to eat the loco almost immediately when out in the pasture, and the effects came in a comparatively short time. The effect of the poisoning on her weight is shown in figure 6.

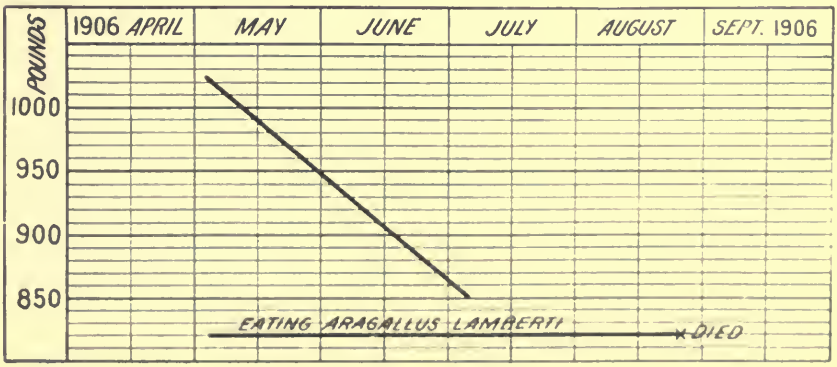


FIG. 6.—Curve of weight of cow No. 32.

Case 34.—This was a cow which commenced to eat loco immediately after being placed in the *Aragallus lamberti* pasture in the spring. She gave birth to a calf on May 3. The calf was weak and unable to stand and lived only a few days. There was really no reason, however, for supposing that the weak condition of the calf was due to *Aragallus lamberti*. She ate *Aragallus lamberti* with great freedom, and early in June it was noticed that at times she would go from

one plant to another, eating nothing at all except the loco weed. Symptoms of loco poison were shown in a marked degree a little before the middle of July. Plate VII, figure 2, shows the condition of the animal at this time, the picture being taken on July 9. It also shows the peculiar crouching attitude which the animal assumed in going through a gate—bending down as though she were attempting to get under a wire. On July 19 she was very poor, had a rough coat, straddled as she walked, and showed marked lack of muscular coordination; she was also very weak. She was kept on *Aragallus lamberti* until August 8. The cow was nervous, had lost control of her muscles to a very marked degree, and showed great difficulty in crossing over even the slightest obstructions. On August 8 she was kept in and fed alfalfa and hay, and attempts were

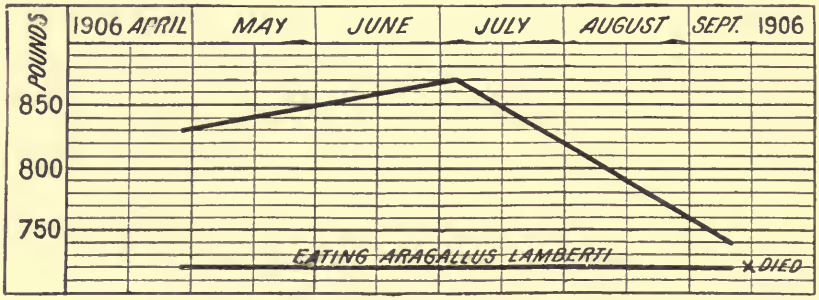


FIG. 7.—Curve of weight of cow No. 37.

made to give her certain medicinal remedies. She grew worse until August 16, when she died and was autopsied.

Case 37.—This was a Hereford cow with a registry tag. She was placed in the *Aragallus lamberti* pasture in the spring and immediately commenced to eat the loco weed. At this time she weighed 830 pounds. She gave birth to a calf April 28. She began to show the effect of the loco poison about the middle of July, and the symptoms increased gradually until August 31, when she would fall down when walking. On September 10 she was kept in the corral, as she was at this time very weak, and was fed hay. She weighed then 690 pounds. On September 11 she was down and remained down until September 14. During this time she would eat very little. On September 14 she was barely alive, and was killed in the afternoon and autopsied. The curve, figure 7, shows the decline in weight resulting from loco poisoning.

Case 45.—This was a cow which was placed in the loco-free pasture in the spring of 1906, weighing at this time 775 pounds. The latter part of May she was taken into the corral to feed fresh cut *Aragallus lamberti* in order to determine whether loco weed might not produce abortion. She was apparently about three months

along with calf. For the first two or three days the hay was omitted from her feed in order to get her to eat the *Aragallus lamberti* more freely. After that time, however, she was furnished with an abundance of hay so that there might be no question of starvation. She ate the weed from the start, although not very freely at first, but soon acquired the habit, and when turned out into the pasture it was noticed that she would go from one *Aragallus lamberti* plant to another, seeming to hunt for the loco, desiring it very much more than grass. On July 21 she was somewhat gate shy, and a few days later her motions in going through a gate very closely resembled those of steer 2. Her calf was dropped on August 5, and it was evident that it was a premature birth. The calf weighed only 14 pounds, was about 24 inches long, the hair was not formed, and it may be assumed that it was not more than six months along.

It would seem probable in this case that *Aragallus lamberti* had induced the premature birth. She continued to eat the *Aragallus lamberti* and gradually grew weaker little by little, losing her appetite and not caring to eat much of anything. On August 18 she was

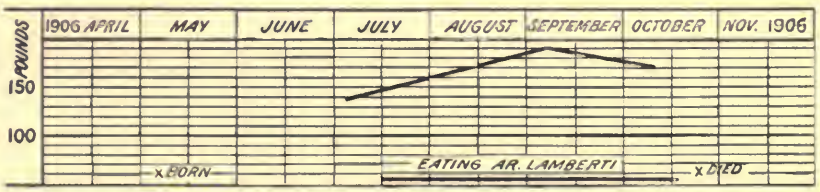


FIG. 8.—Curve of weight of calf No. 66.

down and could not get up. She was fed and furnished water, but did not get up again, and died on August 31.

Case 66.—This was a male calf dropped by cow 32 on May 6. Its weight on July 5 was 138 pounds. By the middle of July it was eating a good deal of *Aragallus lamberti*, and continued to eat it very freely; the effects of the poison were evident by the 1st of August. At that time the calf was decidedly constipated and began to be somewhat dull. On August 9 it was very weak and would not follow the others going to the pasture, but laid down and remained away from the rest of the herd. On September 7 its weight was 190 pounds. On October 9 the weight had become reduced to 170 pounds. On October 17 the animal was taken into the corral for dosing. It was pretty far gone, however, and in a blizzard on October 21 the exposure caused its death.

This case was particularly interesting, as the calf was born of a cow that was eating loco, and presumably learned to eat from its mother. Although a bright, healthy, and strong calf at the outset it made very little gain in weight and gradually succumbed. The curve, figure 8, shows the changes in weight.

Case 67.—This was a Hereford calf dropped by cow 37 on April 28. It was kept with its mother in the *Aragallus lamberti* pasture, and by the middle of June was eating pretty freely of the weed. On July 5 its weight was 160 pounds. Marked effects from the loco eating appeared about the 1st of August, when it became constipated and dull, and in other ways showed symptoms of the poison. The weight, however, increased until September 7, when it weighed 210 pounds. On September 19 it was put in good pasture, with the intention of

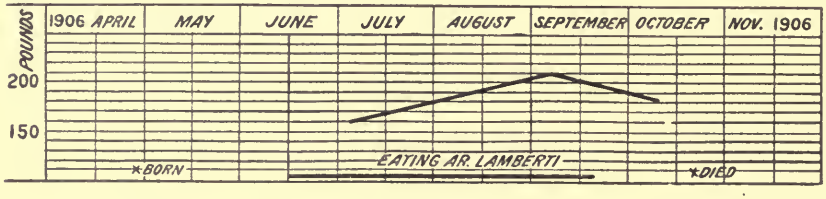


FIG. 9.—Curve of weight of calf No. 67.

making some attempt to cure its locoed condition. From this time on it was kept away from the loco and was dosed. It continually, lost weight, however, and on October 9 weighed only 182½ pounds. Its decline was gradual, and it showed all the symptoms of typical loco. It became very poor, with rough coat, dull eyes, and in walking its head was down in an attitude of peculiar dejection. Plate VII, figure 3, shows the animal soon after birth, when it was a bright and handsome calf. Figure 5, taken October 16, shows the animal

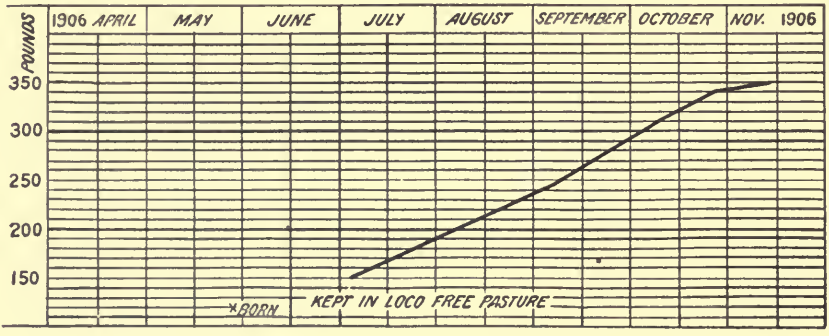


FIG. 10.—Curve of weight of calf No. 68.

when it had all the typical symptoms of loco poisoning. On October 18 it was down in the pasture, and remained down in the same position until its death on October 20. During this time an attempt was made to feed and water it, but without success. Figure 6 shows the attitude assumed by the animal during the last stages.

This was also a particularly interesting case, as the calf was born of a mother that was eating loco, learned the habit from its mother, and gradually succumbed to the disease.

It is of interest to compare this calf with another, No. 68, that was born about a month later. No. 68 was kept in the loco-free pasture through the whole summer. It soon outstripped No. 67 in weight, and at the end of the summer was a strong, healthy calf, weighing 350 pounds. The curves of weight of Nos. 67 and 68 are given in figures 9 and 10.

EXPERIMENTS WITH HORSES.

A few of the cases among the horses in 1906 deserve special notice as being typical of the general results of loco feeding.

Case 16.—This horse had been in the loco-free pasture during the season of 1905 and until June 11, 1906. From that time on it was fed *Astragalus mollissimus* and hay. At first the amount of hay was very small in order to induce it to eat more of the loco, but later on the amount of hay was increased, so that there might be no question in regard to the possibilities of starvation. The animal was kept

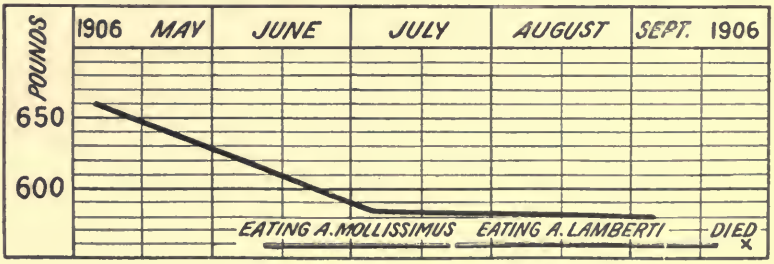


FIG. 11.—Curve of weight of horse No. 16.

upon this diet until July 21. During this time it lost in weight about 60 pounds. It was noticed that it ate the loco in a very variable manner; sometimes very little and at other times very freely. On July 22, as it had become impossible to obtain sufficient of the *Astragalus mollissimus*, the horse was put in the *Aragallus lamberti* pasture, remaining there until July 31, when it was taken in from the pasture and fed *Aragallus lamberti* and hay. This diet was kept up until September 19, when the horse was taken up for treatment, but it continued to grow worse and died September 25.

In this case there was decided trouble with the lungs as well as the ordinary loco symptoms. Plate VIII, figures 1 and 2, show the effect of the loco upon the animal. The curve, figure 11, shows the loss in weight.

Case 50.—This was an old horse that had evidently been worked for many years. It was received in the spring of 1906, and on arrival at the station was very poor, weighing only 670 pounds. It

was placed in the *Aragallus lamberti* pasture and immediately commenced to eat more or less of the loco plant. It gained somewhat in weight, weighing 695 pounds on July 18. Plate VIII, figure 5, shows its condition at this time. On September 7, however, it weighed only 660 pounds, having lost a good deal of flesh. It continued to eat *Aragallus lamberti* until September 16. On this date it disappeared from the station and was located several miles away, and the attempt to drive it in brought out the fact that it was not only poor but very badly locoed in every way. It was blind in one eye, probably having received the injury by running into a barbed-wire fence. It would walk directly into a fence, not stopping until actually cut by the wire. When driven, it would turn to one side and then move straight ahead, not stopping until it ran against a fence. In order to turn the animal it was necessary not only to get in front of it, but to strike it over the head. It was very poor at this time, but seemed to have a good deal of strength. On September 17 it was driven out,

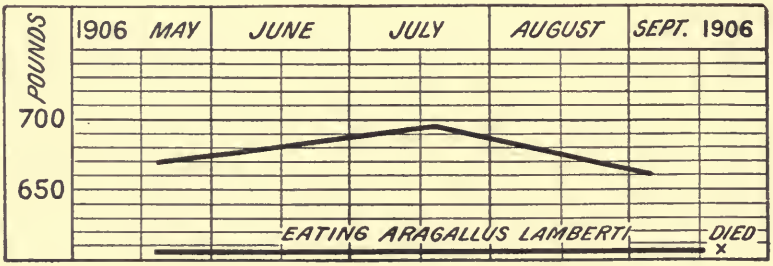


FIG. 12.—Curve of weight of horse No. 50.

but showed no sense of direction whatever in regard to the place it should go. Plate VIII, figure 6, shows its condition. The picture also shows very clearly the cuts upon its head which had been caused by running into a barbed-wire fence.

An attempt was made to treat the animal, but without any effect. On the morning of September 19 it was found dead. It had broken through three corral fences and had fallen down into a hole which had been dug for a cellar. Although the animal was old it was nevertheless strong, and in the early part of the season was in very good condition. Its end was doubtless due to the effect of the loco. Figure 12 gives the curve of its weight.

Case 52.—This was of interest as being one of the few cases of mules experimented upon. The animal was put in the *Aragallus lamberti* pasture early in the spring of 1906 and at first apparently ate none of the loco. Toward the end of May, however, some two weeks after it had been placed in the pasture, it was noticed that it not only ate *Aragallus lamberti* freely, but seemed to care for nothing

else. At this time it would pick off the leaves, but would not eat the flowers. It passed from one plant to another, eating them with great greediness. On June 18 it was weighed and found to weigh 590 pounds, a gain of 40 pounds from the time it was placed in the pasture. When weighed on September 7, heavy loss was shown, as it then weighed only 505 pounds. The mule was kept in the *Aragallus lamberti* pasture, but it was noticed on September 13 that it was not eating at all. Rather to our surprise, on the morning of September 15 it was found dead. It was thin, but nevertheless seemed to be quite strong. Plate VIII, figure 3, shows its condition in the spring, when the experiment commenced; figure 4, September 7, shows its peculiar attitude, with all the symptoms of loco poisoning very marked. Text figure 13 gives the curve of weight.

Case 59.—This mare was placed in the loco-free pasture during the early part of the season. She was about 8 years old and never had

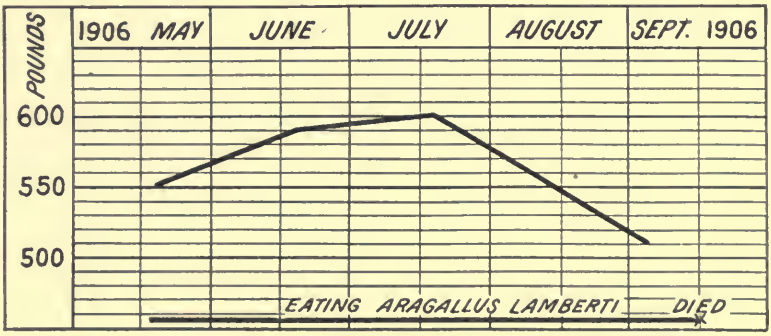


FIG. 13.—Curve of weight of horse No. 52.

been broken. She had a peculiar congenital malformation of the fetlock joints. Except for this defect, however, she was entirely sound and healthy. She increased in weight, and when, on July 18, she was placed in the *Aragallus lamberti* pasture she weighed 885 pounds. On September 7 she weighed 830 pounds. During this time she ate comparatively little of the *Aragallus lamberti*, and on September 18 she was taken into the corrals in order to hasten the effect of poisoning by forced feeding of *Aragallus lamberti* and hay. This feeding was continued until October 20, when for about a week she was in the *Aragallus lamberti* pasture. On the 28th it was noted that she was getting exceedingly poor and that the nervous symptoms were very marked. From that time on she was kept in the corral, fed hay and chop, and was treated, the treatment continuing through October and November with no apparent effect. This loss of flesh was particularly noticeable, because when she was taken into the corral to commence the feeding of loco she was an especially smooth,

handsome-looking animal, and the loco effect came very quickly and in a very marked way. She was taken to Fort Collins in December in order to continue the treatment during the winter, but died on the road. This was a typical loco case, the symptoms were marked and distinct, and the case is particularly interesting because the effect of the poison came in such a short time. Text figure 14 shows the curve of weight.

EXPERIMENTS WITH SHEEP.

Through the kindness of local sheep owners near Hugo considerable work on sheep was possible during the season of 1906. These sheep were numbered as received and were kept in the corral nights and herded in the neighborhood of the experimental ranch and on a pasture which was pretty well covered with *Aragallus lamberti*. Some of the sheep were very weak when received and in bad general condi-

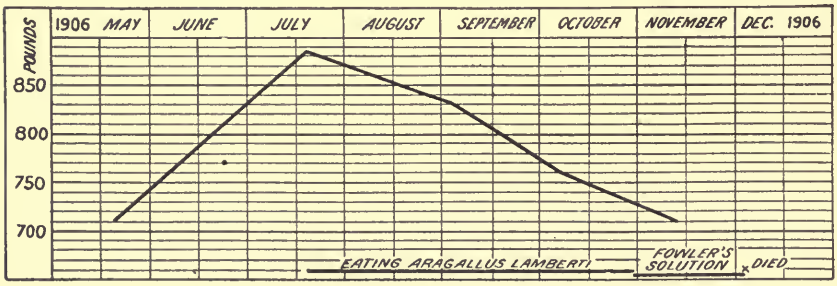


FIG. 14.—Curve of weight of horse No. 59.

tion. During the season 69 were used in the experiment, 63 being bucks a year old and 6 lambs. All were supposed to be locoed at the time when they were received.

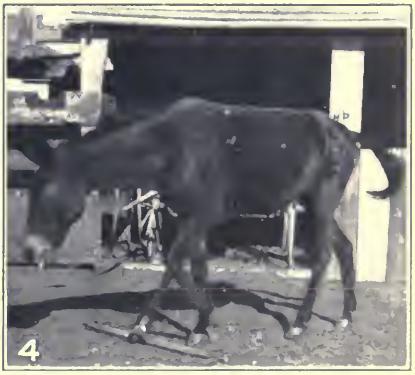
In the early autopsies special attention was paid to the presence of parasites, particularly the grubs of *Œstrus ovis*. The symptoms of this disease (grub in the head) are very similar to the symptoms of loco, and there was a possibility that the so-called locoed sheep were not locoed, but were affected by this parasite. *Thysanosoma actinioides* was also found in greater or less numbers in the duodenum or in the bile ducts, or in both.

Inasmuch as in the former investigations on locoed sheep under the direction of Doctor Marshall, a partial report of which was made in the Johns Hopkins Hospital bulletin, the very definite conclusion was reached that so-called locoed sheep were infested by these two parasites, and that if the parasites were removed the cause of the trouble would also be removed, these early autopsies were particularly interesting.

Case 16, June 6, 1906. Horse before eating loco weed.

Case 16, September 15, 1906. Animal shown in Fig. 1, in an advanced stage of loco poisoning, emaciated and extremely weak.

Case 52, May 19, 1906. Mule in fairly good condition before feeding upon loco weed.



Case 52, September 7, 1906. Mule shown in Fig. 3, in last stages of loco poisoning.

Case 50, July 19, 1906. An old horse before being fed with the loco weed.

Case 50, September 18, 1906. Same animal as in Fig. 5, showing effect of loco poisoning in attitude and emaciated condition; also shows cuts produced by running into barbed wire fence.

A group of locoed sheep, showing the general appearance of locoed animals.

Sheep 27. A locoed sheep in last stages of poisoning.

Sheep 36. Effect of loco poisoning combined with grub in the head.

Same as Fig. 3, in a different attitude.

Case 66, October 20, 1906. A locoed lamb.

Case 66, November 12, 1906. Attitude of the animal just before its death.

If the sheep were affected with loco poisoning it was evident that the effect of the loco was complicated by the parasites, and, of course, it might be possible that the primary trouble was not poison by loco plants, but the effect of these parasites. It therefore seemed desirable, if possible, to remove the parasites, and thus do away with the sources of complication. In this work of removal, however, the results proved that we were only partially successful.

Five of the sheep were given gasoline and milk as a vermifuge. Three of these were autopsied, with the result that one was found with many tapeworms, the other two with a few. It would appear, then, that the work of the vermifuge was only partially successful. It may have reduced the number of tapeworms, but it certainly did not clean them all out.

Four sheep were treated for *Œstrus ovis*. In two of these, holes were drilled into the frontal sinuses, and about a teaspoonful of gasoline injected into each side; they were then washed out with a fountain syringe with water containing a little gasoline. Of these two, one was operated upon on May 10 and died August 18, when there were still some individuals of *Œstrus ovis* in the frontal sinuses. The other was operated upon on May 9 and died the 21st, at which time 8 living grubs and several dead ones were taken out of the frontal sinuses and nostrils. Inasmuch as during the operation of washing out a considerable number of *Œstrus ovis* were seen to come from the nostrils, it is known that the operation was partially successful. It would appear, however, that in neither case did it entirely rid the animals of the grubs.

The other two cases were treated by injecting gasoline into the nostrils. In neither of these, unfortunately, were we able to make autopsies, so that the result of the experiment was not known.

A similar experiment was tried on some sheep in the season of 1907. Sheep Nos. 74, 77, and 80 were treated by injection of about a teaspoonful of gasoline into each nostril. One of these was later killed by a coyote. It was autopsied and no grubs were found in the frontal sinuses. Inasmuch as we feel certain of the diagnosis of grub, it would seem that in this case the treatment with gasoline was successful. Of the two others, No. 77 was in bad condition when treated, but immediately began to get better. No. 80 was also in better condition after treatment. It seems probable that in all these cases the gasoline treatment for *Œstrus ovis* was successful.

Soon after the first lot of bucks was received in 1906 an experiment was made to see whether they would eat loco readily or not. Hay mixed with *Aragallus lamberti* was placed in the corral where the sheep were confined. It was noticed that 12 of them would eat the weed to some extent. None of them ate very greedily, but

they would pass by the pile, perhaps pick up a single plant, and then pick up more hay. The others did not eat the plant at all. This preliminary experiment seemed to show that none were anxious to eat the loco and that many did not care to eat it at all. As the season went on, however, all of them ate more or less of the *Aragallus lamberti* in the field, sometimes eating a considerable amount and at other times only eating a little. Inasmuch as sheep have a way of nibbling at anything, it was sometimes rather difficult to tell whether they had a real passion for the weed or not. There were some, however, that would go from plant to plant and devote themselves for at least a portion of the day to eating nothing at all except *Aragallus lamberti*. It was also rather difficult to tell to what extent the animals were affected by the weed. Many of them were rather poor and weak. Some of them were more or less erratic in their movements, and as the season went on this became more pronounced. Instead of keeping together in a bunch as normal sheep do, they would scatter in groups of two or three, while sometimes a single animal would stray off by himself. It thus became increasingly difficult to care for them properly, as it was impossible to keep a herder with them all the time. Sometimes some of them would be lost for a day or two, and some disappeared never to return, having fallen prey to the coyotes.

Plate IX, figure 1, shows the general character of the sheep received from Mr. McIntyre in the spring. The cases all resembled each other very closely. Attention, perhaps, may be called to two or three of them, with the accompanying illustrations, as showing the typical condition of locoed sheep.

Sheep 27.—This was badly locoed when received and lived only a few days. Attention is called to it because the picture (Pl. IX, fig. 2) shows the typical appearance of a locoed sheep in the last stages of the disease.

Sheep 36.—This was interesting as being an animal upon which an operation was performed to rid it of *Œstrus ovis*. There seems no question that the operation was partially successful, although not completely so. The sheep was an old buck, perhaps 5 or 6 years old, and, except for his emaciation, was rather a handsome animal. He was kept about a month, when he died, his death without any doubt being the result of the loco poison. Plate IX, figures 3 and 4, show the condition of the animal.

Lamb 66.—In Plate IX, figures 5 and 6, are shown the peculiarities of locoed lambs. This was a lamb received in October, and was badly locoed. As the picture shows, the animal was in good condition so far as flesh was concerned. However, it was weak, staggering about in typical loco fashion. Plate IX, figure 6, shows the dull, dozy condition of the animal, the photograph having been taken only a short time before its death.

In 1907, besides a locoed wether presented by the Hamp Brothers, we had 15 bucks brought in by Mr. McIntyre on June 17. The history of these 15 bucks was of special interest because it differed so much from that of the sheep brought in by the same owner the preceding year. When they were delivered at the experiment station they were all poor, some of them staggering more or less as they walked, and they were considered by the owner and other sheepmen who saw them as typical specimens of locoed sheep. They resembled in their general appearance very closely the sheep that were used for experiment in 1906. From the very beginning, however, their behavior was different. While those of 1906 would feed where loco was abundant, confining their pasturage very largely to such localities, those of 1907 sought the lower land, where there was no loco but more grass, and even when the loco was abundant about them they paid very little attention to it. While the sheep of 1906 would scatter, going off in groups of two or three or individually, those of 1907 kept together and behaved more like normal animals. They were fed a little grain daily, mainly to accustom them to have a habit of coming to the corrals at night, but not enough to make any great difference in the formation of flesh. Nearly all of them gained through the summer, and were returned to the owner in good condition.

A few of these sheep, as explained elsewhere, were treated for *Œstrus ovis*. Most of them had discharges from the nose, in many cases bloody, and it is possible that the real trouble with the band was not loco but the grubs of *Œstrus ovis*. As is well known, animals generally recover from attacks of this grub, and it may be that the improvement of the sheep in question was due to the loss of the grubs in the course of the summer.

There is no doubt that nearly all of the sheep which were kept at the ranch in 1906 were locoed, and just as little that few if any of the band received in 1907 were affected by the loco poison. The experiments with sheep were, therefore, of particular interest as showing how easily the effects of grub in the head may be confused with loco poisoning. Incidentally, it would appear from our work that the injection of gasoline into the nostrils of sheep that are infested with the grub of *Œstrus ovis* is likely to be followed with excellent results.

DISCUSSION OF THE SHEEP EXPERIMENTS.

Sixty-three of the 69 sheep used in the experiment of 1906 were bucks a year old or more, and 6 were lambs. All were supposed to be locoed when they were received. Autopsies were held upon 33 of the cases. In the autopsies special attention was paid to the presence of parasites because of the conclusions reached by Doctor Marshall, which have already been summarized in the discussion of the literature. Of the 33 on which autopsies were held, 23 had grubs of

Œstrus ovis. These were present in some cases in considerable numbers, and their presence was indicated before death by a bloody discharge from the nostrils. One case, No. 23, was considered to have died as the result of the presence of this grub. Twenty-three of the 33 were infected with *Thysanosoma actinioides*. In most cases, however, this tapeworm was not present in large numbers. In some the bile ducts were much distended with them, but commonly the numbers were rather small, and perhaps not more than would be expected in an animal which is so subject to parasitic infection. Cysticerci were found in 6 of the cases, but there is no reason to think that they affected the animals injuriously. In 13 of the post-mortem cases the inner walls of the fourth stomach were inflamed; 9 had blood clots in the lateral ventricles; 15 had an apparently abnormal number of hemolymph glands in the dorsal parts of the thorax, or the abdominal cavity, or both, and in 18 there was a serous coagulum present in the epidural space of the spinal canal.

In the experiment of 1907 most of the sheep were not seriously affected by the loco poison, but were suffering from other causes, the evidence tending to show that the presence of *Œstrus ovis* was in part at least responsible for their condition. The principal difficulty with most of the animals in 1906 was the loco poison, with the effects complicated by parasites. On the other hand, it seems that the chief trouble with most of the sheep in 1907 was caused by the parasites and that the loco had little if anything to do with their condition. It is evident from our work that it is very easy to confuse the effects of parasites with those of loco poisoning. The general appearance of the bands of sheep in 1906 and 1907 was the same, and not only the author, but experienced sheepmen, declared that both bands were locoed. In the majority of cases it was only by post-mortem examination that the diagnosis could be confirmed. These statements refer, of course, to the general symptoms. If the habits of the sheep are observed there is a marked difference. The sheep affected with *Œstrus ovis*, except when they are in very bad condition, keep together like normal animals, and show a preference for good food, although they may at times eat loco. The locoed sheep, on the other hand, are more erratic, and develop a solitary habit to a greater or less extent. They show, too, a marked fondness for the loco weed. At the same time, when one is dealing with a considerable number of sheep, it is a matter of much difficulty to separate the locoed animals from those affected with grub in the head. It is not strange that in experiments where sheep only have been used those in charge have been led to the belief that the so-called locoed sheep are sheep infested with parasites, for the symptoms bear a close resemblance. Moreover, it is very possible that in individual experiments the supposed locoed sheep were in fact not locoed at all.

It is a matter of considerable interest that lambs are much more quickly affected than older animals. Attention was first called to this fact by Mr. A. McIntyre, who stated that lambs would frequently succumb to the poison in two or three weeks, and with little loss of flesh. The author's observations were completely confirmatory of this statement. Of the 6 lambs under observation (Nos. 65 to 70), all were in good flesh, but very distinctly locoed. Post-mortems were held on 5 of these, and the results were very interesting. All had clots in the lateral ventricles. All had serous coagulum in the spinal canal, and all had congested walls of the fourth stomach. This would seem to confirm our opinion that these lesions are characteristic of the locoed condition, but that in chronic cases they may be more or less masked.

EXPERIMENT AT WOODLAND PARK, COLO.

The loco conditions were so different in the mountains that it seemed wise to conduct a feeding experiment to determine to what extent the phenomena would differ from those in the plains. The loco plants grow in the mountains to an elevation of 8,000 to 10,000 feet, and among the stockmen pasturing horses and cattle in these localities there are plenty of stories of locoed animals. The principal loco plant in the region where the experiment was carried on is *Aragallus lamberti*, but with this are associated a great many plants of *Astragalus nitidus* and a smaller number of *Astragalus splendens*. In the summer of 1906 land was offered for an experiment between Woodland Park and Divide, on the Colorado Midland Railroad. A particularly thick field of loco was fenced in for a loco pasture, and an adjoining piece with very little loco was used as a control pasture. Eleven horses and 12 head of cattle were used in this experiment, 6 of the cattle being donated by the Crescent Cattle Company, of Cripple Creek.

The horses were put in the pasture July 13—6 in the loco pasture and 5 in the control pasture. A week later 6 head of cattle were received and were divided, one-half being put in each pasture. On July 27 horses 73 and 74 were taken into the corral, where they were kept through the rest of the season, and fed on cut loco, with an abundance of hay. On August 14, 6 more cows were received and were divided between the two pastures. The cattle ate loco readily, and before the season was over cleaned out the pasture pretty thoroughly. The horses would not eat loco in the field, but those in the corral ate quite freely. None of the cattle showed any positive effects as the result of the loco eating. The horses in the corral grew thinner, became dull, and showed a somewhat stiffened gait. The lack of more general results in this feeding experiment was due in part probably to the comparatively short time during which the experiment was

carried on. It was unfortunate that we were unable to install the experiment earlier in the season.

The animals remaining in the fall of 1906 were taken to the ranch of the Crescent Cattle Company, where they were kept during the winter, receiving the ordinary treatment of the range stock owned by that company. During the winter horses 73 and 74 died, their death doubtless being occasioned by the weakness produced by the loco poison during the preceding summer.

In 1907, 8 horses and 8 cattle were pastured at Woodland Park; part of these, as in the preceding season, were kept in the loco pasture and part in another past[illegible] comparatively free from loco. It was found, however, as the season progressed, that the so-called loco-free pasture had considerable of the plant in it, and some of the animals which were pastured in it became locoed in spite of the small temptation. As in the preceding season, we were unfortunate, because of a series of events entirely beyond our control, which made it impossible to start the real experiment until comparatively late.

The animals ate the loco readily, but none of the cattle were clearly locoed. Horse 76 was put in the loco pasture on June 11, and was badly locoed on August 6. This locoed condition was evident in her extremely nervous manner. She was easily startled and ate in a nervous way, as if frightened. She had the high step peculiar to locoes and the straddling attitude of the hind legs when she walked, and would rear when startled. At this time, however, there was no loss of flesh, but toward the end of August she showed a distinct loss of flesh, and on August 31 was taken up for treatment, the result of which is given elsewhere.

At the end of the season the stock was taken to Hugo to be pastured during the winter. At this time 5 of the 8 horses were distinctly locoed, but none of the cattle showed the effects of the poison.

The principal result of the two years' feeding at Woodland Park seemed to indicate that stock is not as easily locoed in the mountains as in the plains, and that horses are much more easily locoed than cattle. The latter fact seems to be in harmony with the results of experience, for there are very few complaints of locoed cattle in the mountains. A number of factors may explain the smaller number of locoed horses in the mountains. The loco is not so abundant as in the plains, commonly being restricted to smaller areas, while the grass is more abundant and commonly does not dry out, as it does on the plains, so that the animals are not forced upon the loco because of lack of other food. It is very possible, too, that the amount of the poison in the mountain loco is not as great as in the plants of the plains. This can only be determined by extensive laboratory experiments, for which thus far there has been no opportunity.

EXPERIMENT AT IMPERIAL, NEBR.

This experiment was carried on in cooperation with the experiment station of the University of Nebraska, which was represented in this work by Dr. A. T. Peters. The work was located at Imperial, in the southwestern part of Nebraska, and the animals for the experiment were donated by local stockmen. The loco in this section consists almost entirely of *Astragalus mollissimus*. The work was under the immediate supervision of Mr. L. B. Sturdevant, of the University of Nebraska.

In this feeding experiment the attempt was made to get results from the loco as rapidly as possible. With this end in view the animals were herded on the loco part of the time, and part of the time the weed was cut and fed to them. In the feeding experiments hay was always used as well as the loco, in order that there might be no question of starvation. The work was started about July 4 and was carried on to the end of October, when all the animals eating loco were dead. Only horses were used in this experiment, and the number was unfortunately much too small. All contracted the disease, however, and died with the typical symptoms of locoed animals, showing the same post-mortem phenomena as were exhibited in the animals studied in Colorado. Careful post-mortems were made, and the general results of the work served to confirm that carried on at Hugo. Thus the work in Colorado was supplemented in an important way, for it was impossible during the season of 1906 to obtain in the neighborhood of Hugo very much of the *Astragalus mollissimus* for feeding experiments.

REMEDIAL MEASURES.

In the work of the first season no attempt was made to experiment with remedies for the loco disease. The knowledge of the subject was so indefinite that there seemed to be no adequate foundation for such work. It seemed better to devote all our energies to getting a diagnosis of the disease and determining its cause before attempting to apply any remedies.

During the second season, however, it appeared that the correct diagnosis of the disease was gradually being evolved as the result of our observations, and it seemed best to make some tentative experiments with remedies. Inasmuch as most locoed animals are constipated, it was clear that something to produce free action of the bowels was of first importance. This would be true not only because it was desirable to have healthy action of the intestines, but because it would be presumed that a free action of the bowels would aid in eliminating whatever poison had been absorbed. The remedy used for this condition of constipation was magnesium sulphate.

When this was first used, the chemistry of the loco plant had not been worked out, and the reason for its use was simply to correct constipation. As it turned out later from the laboratory work, in this substance we were using the most probable antidote for the barium poison. This information, however, came too late to make it possible to experiment with antidotes. It would seem possible to arrange to give small doses of a sulphate which should neutralize the effects of the extremely small amounts of barium in the loco. Doctor True has suggested that this might be done in connection with salting the stock. It may be that through the food or drink it will be possible to give enough of an antidote, so that whatever effect the barium has may be nullified. Further experiments to this end will be made.

The effects of loco poisoning come on very slowly as a rule and after a long period of feeding. This period may not only be many days, but frequently months, and in some cases even years. The locoed condition seems to be the accumulated effect of a multitude of small doses of the poison, and the cure of the animals would most probably be sought in a treatment of the general condition of the animal rather than in any special treatment to counteract the effects of the poison. The most marked symptoms of locoed animals are the nervous phenomena and the anemia. These conditions were those that were especially considered in planning remedies. It seemed wise to pay more attention to building up the animals than to attempt to use an antidote. Several remedies were used which were clearly proved to be useless. One of these was potassium iodid, with which a fairly thorough trial was made. Asafetida, valerian, and caffein were tried, but with no good results. Strychnin seemed a logical remedy for the most evident symptoms, and was tried with a number of animals with varying results. Nine head of cattle, 3 horses, and 5 sheep were treated with this remedy. Most of those treated were in bad condition, and it was a fair question whether in any of these cases unfavorable results should not have been expected, or, rather, whether they would not have died in spite of all treatment. Two of the cattle made somewhat remarkable recoveries.

Two of the cattle were cured during the strychnin treatment and there seemed no good reason why this drug should not have the credit of the cure, but it was true that other animals treated with strychnin died, in some cases partly, at least, as the result of the poison. None of the horses showed improvement from the use of strychnin. The fact that several of the animals showed indications of poisoning made it probable that strychnin was administered in too large doses, although only the minimum doses of the ordinary veterinary materia medica were used. It seemed probable that locoes

perhaps were more sensitive to the effects of the drug and should be treated in especially small doses.

Arsenious acid effected a cure in one of the horses. This animal was treated at the agricultural experiment station during the winter of 1906–7 under the general direction of Doctor Glover, and while it was a clear case of loco in the fall of 1906 with all the typical symptoms, it came out in the spring definitely and apparently permanently cured. This animal was used as a saddle horse during the summer of 1907 and at no time showed any of the signs of loco poison, if we except a slight loss of spirits.

One of the cattle, too, after it was treated with Fowler's solution, was completely cured.

TREATMENT WITH STRYCHNIN IN 1906.

Case 4 was a steer that had been kept in the loco-free pasture during the season of 1905. In 1906 it was at first placed in the loco-free pasture, but on May 3 was put in the *Aragallus lamberti* pasture, where it commenced to eat the weed and continued to eat it with considerable freedom. Gradually the poison began to show its effect, and by the latter part of August the animal was recognized as a typical loco. It was in excellent condition at the beginning of the season, when turned into the *Aragallus lamberti* pasture. Plate X, figure 1, shows its condition May 30, 1905; figure 2, taken September 7, 1906, shows its condition on that date, when it was very distinctly under the influence of the poison. In this picture the attitude is that of the typical loco. It had lost flesh and showed nervous symptoms in the way of responding with convulsive movements to sudden sounds, and when made to run its head would shake with the palsied movement which is characteristic of many locoed cattle. In figure 3 may be seen the serous sac under the jaws, one of the typical symptoms of loco poisoning in cattle. The steer was taken up on September 20 for treatment and was given daily one-quarter grain of strychnin hypodermically until September 30, when the dose was increased to one-half grain. During this time it did not gain in weight, but the nervous phenomena gradually disappeared. The doses were kept up until October 6. From that time until the end of the season it was kept in the loco-free pasture. When it was sent away for the winter on November 20 it seemed to have entirely recovered so far as nervous symptoms were concerned. Figure 4 shows the animal's condition August 22, 1907.

The curve of weight for 1906 (text fig. 15) shows that this steer did not make normal gains. The loss for the end of October and for November, however, is the normal result for that time of the year. Storms and shortness of food caused losses that year in all the ani-

mals at that period. In the spring of 1907 the animal was kept in the loco-free pasture about one week. During the rest of the summer it was kept in the good pasture until September 18. From this time until October 28 it was herded on loco. As the curve shows (fig. 16), it gained during this time about 300 pounds. Plate X, figure 4, shows that on August 22, 1907, while in the loco-free pasture, the

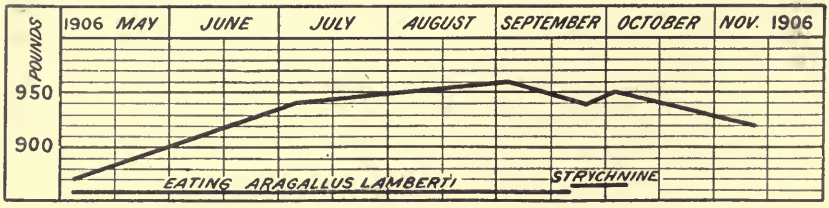


FIG. 15.—Curve of weight of steer No. 4, 1906.

animal was in fine condition. When it was kept on loco, however, it ate freely and at the close of the season it again showed distinct symptoms of loco poisoning, although it was not a bad case.

Another case, No. 536, was a Hereford steer belonging to Mr. Mattix, of Hugo, which was brought to the station for treatment on July 9. It was at this time extremely poor, its coat was rough, its

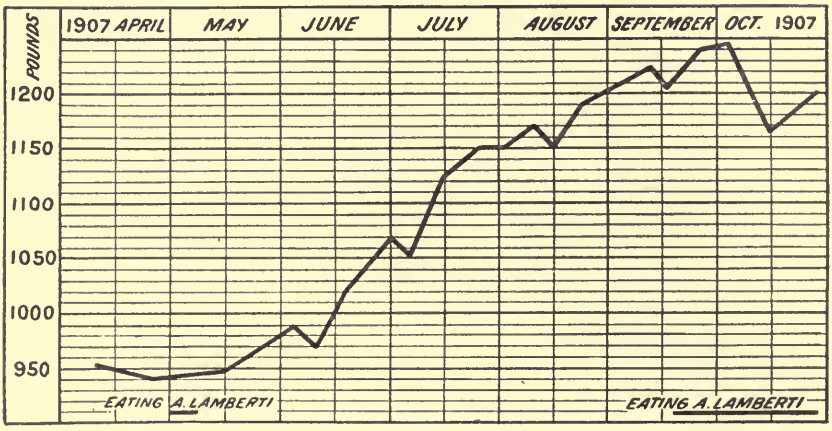


FIG. 16.—Curve of weight of steer No. 4, 1907.

eyes staring, and it stood with head low and legs spread apart because of evident weakness, and with a peculiar curvature of the fetlock joints of the hind feet which is sometimes noticed in locoed animals. Plate X, figure 5, shows very clearly the condition of the animal at this time. It appeared a hopeless case, because the animal not only showed the effects of poison, but was extremely weak. It was kept in the corrals, as it was too weak to be sent out into the pastures.

Case 4, May 30, 1905. Before feeding on loco weed.

Case 4, September 7, 1905. Showing all the typical symptoms of loco poisoning.

Case 4, September 15, 1906. Animal under influence of loco and with a noticeable accumulation of serous fluid under chin.

Case 4, August 22, 1907. Same animal as in Figs. 1 to 3, in the succeeding year, when it no longer showed symptoms of loco poisoning.

Case 536, July 9, 1906. A locoed steer with curvature of the fetlock joints, which is peculiar to some locoed animals.

Case 536, July 25, 1906. The same animal after treatment with strychnine. It stands in normal fashion and has gained much in strength and in weight.

It was fed upon alfalfa hay and some grain, and was given hypodermically one-half grain of strychnin daily. The strychnin seemed to take effect upon it almost immediately and on July 11 its fetlock joints had straightened out and the animal showed itself in every way very much improved. The doses of strychnin were kept up from July 9 until July 21. Most of this time the action of the bowels had been very free, but as at this time it seemed somewhat constipated, it was given 250 grams of Epsom salts, and was turned into the loco-free pasture, where it was kept until July 30, when it was brought in and given another course of strychnin, one-half grain daily until August 6, when it was again turned into the loco-free pasture and was considered as very nearly cured. Plate X, figure 6, shows its improved condition on July 25. About October 1 it was turned back to the owner, who sent it out upon the range with his other cattle. The animal was seen again about the end of October and it was evident that the cure was complete and permanent. Later in the season the steer was put upon the market.

Case 40 was also treated with strychnin. This was a large, handsome steer which was received in the spring and kept in the loco-free pasture until July 18, when it was placed in the *Aragallus lamberti* pasture. It immediately commenced to eat the loco, and from this time on ate it with rather unusual freedom, seeming to prefer it to grass. The daily notes taken by the observers in the pasture indicate that it ate loco rather more freely than any of the other cattle. Its weight was 1,235 pounds when put in the *Aragallus lamberti* pasture. It gradually lost weight, and on October 16 weighed 1,160 pounds. Shortly after this the loco symptoms became very marked. The peculiar condition of the hind fetlock joints which was noticed in No. 536 was very marked in this animal also. At the end of October the steer was taken up for treatment. At this time it weighed 1,105 pounds. It was treated hypodermically with one-half grain strychnin daily and fed in the corrals with hay and chop. This treatment was continued until November 5. On November 12 its weight was 1,025 pounds. It was taken from Hugo to Fort Collins to continue treatment through the winter. From December 9 until December 20 it was given one-half grain of strychnin daily and showed a slight gain in weight. The treatment was then discontinued for a time, but was commenced again December 28 and continued in doses every second day until January 9. On January 31 it weighed 1,210 pounds. Two weeks later it had increased to 1,300 pounds. It was fed, of course, with considerable care, and on February 23 was sold for fat beef. It was at that time in fine condition. The curve, figure 17, shows the relation of the changes in weight to the feeding of loco and treatment.

During the season of 1906 none of the horses treated with strychnin showed any improvement, and the same can be said of the sheep. It may be stated that the doses of strychnin in the case of both horses and cattle were either one-quarter or one-half a grain, and in the case of the sheep from two-twentieths to eight-twentieths of a grain.

There was no question that in some cases there were symptoms of strychnin poisoning, and this was true of cattle, horses, and sheep. It seemed probable that the doses of strychnin were too large, so that in the weakened nervous condition of the animals they were affected unfavorably. It appears that locoed cattle may be unusually susceptible to the influence of strychnin. At the same time the extremely favorable results in the cases of Nos. 4, 536, and 40 made it seem desirable to make further experiments with strychnin, but with the use of much smaller doses.

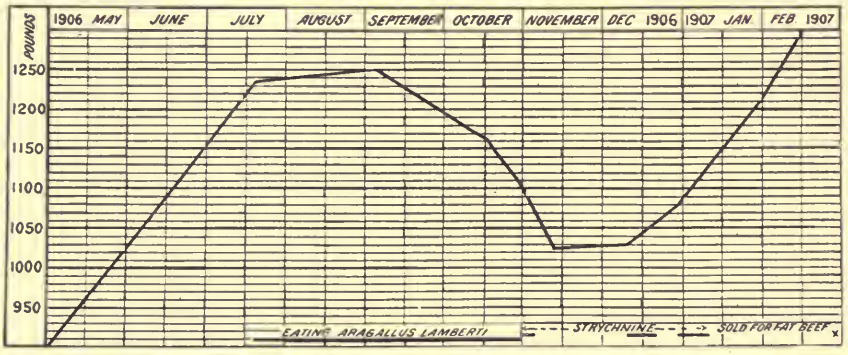


FIG. 17.—Curve of weight of steer No. 40.

TREATMENT WITH ARSENIC IN 1906.

Arsenic either in the form of Fowler's solution or of arsenious acid was used with 3 horses, 4 cattle, and 4 sheep. Two of the horses died, one (No. 58), a mare, was cured. The history of this case is given in some detail.

The mare was received from the Fort Collins Agricultural Experiment Station on May 18, and was placed in the loco-free pasture. Her weight at this time was 655 pounds. She had been an old saddle horse, was a lively, spirited animal, although not young, and in June was used as one of the saddle horses at the station. It was found, however, that her nervous disposition made her somewhat undesirable for general work, and on July 30 she was put in the *Aragallus lamberti* pasture and kept there until October 9. During this time there is no evidence that she ate any of the loco weed. Apparently she devoted herself entirely to grass. On October 9 she was taken into the corral and fed cut *Aragallus lamberti* and hay. At this time

she weighed 765 pounds. She was kept during the remainder of the season upon this treatment.

After October 16 the mare gradually lost in weight and on November 12 weighed only 705 pounds. At this time she was weak and in her peculiar nervous actions showed very decided loco symptoms. She would start at sudden noises and would rear when any sudden motion was made near by. She was taken to Fort Collins for treatment during the winter, under the general direction of Doctor Glover. It was reported from there on December 14 that she was very badly locoed. She reared when excited, and could not be led or tied. This in spite of the fact that she was a so-called gentle horse and had been used for several years. On December 16 treatment was commenced by giving her 2½ grains of arsenious acid in chop. This treatment was continued until January 8. On January 9 she weighed 805 pounds, which was a very marked gain, as on December 12 she weighed only 740. On March 1 she weighed 865 pounds. It was reported at this

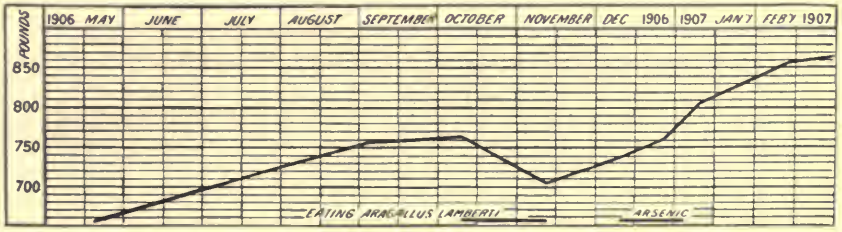


FIG. 18.—Curve of weight of horse No. 58.

time that the man in charge of her tried to ride her, but could not manage her well, and that she would not lead. Her legs were slightly swollen on this date, probably from an overdose of arsenic. No further treatment was given beyond good feed, and she was taken to Hugo in the middle of April and placed in the loco-free pasture. For about a week in May she was herded upon *Aragallus lamberti* and ate it with some freedom. She was then put back in the loco-free pasture, having shown no symptoms of poisoning, and a little later, May 10, was again used as a saddle horse. It was found that she was entirely reliable and showed none of the symptoms of loco poisoning, if we except a slight lack of spirit. She was used during the whole summer in the general work of the station as a saddle horse and did the work well. This was an evident case of cure and presumably the arsenic was instrumental in effecting it. Unfortunately we have no good pictures showing the progress of the disease and cure of this animal. The curve (fig. 18) shows her changes in weight while under treatment.

Of the horses that died while being treated with arsenic, one was a very bad case and probably could not have been saved by any

method of treatment. The other was a good case for treatment, but died in spite of all that was done for her. This case (No. 59) became worse very rapidly, there being only eighteen days of treatment with Fowler's solution before the animal died. It may be considered, perhaps, as a case of rather acute poisoning.

Of the sheep treated with Fowler's solution, all but one died, and we did not feel at all certain that the cure of this one was due more to the Fowler's solution than to the effect of good food.

Of the cattle treated with Fowler's solution, all but one died. The one cured (No. 28) was an old milch cow which was received from Denver and at first placed in the loco-free pasture. She was kept there until June 18, when she was brought into the corrals and fed on *Astragalus mollissimus*. At that time she was heavy with calf, and inasmuch as the loco weeds are popularly supposed to produce abortion, it was desired to feed this animal loco to see whether any effect would be produced on the birth of the calf. She was fed in the corral from June 18 until July 22, with the exception of occasional days in the loco pasture, her rations consisting of fresh-cut *Astragalus mollissimus* and hay. She ate both with very great freedom and showed a strong appetite for the loco weed. By the end of July it was necessary to terminate the experiment with the *Astragalus mollissimus* because it was found impossible to obtain enough for feeding purposes, and on August 2 we commenced feeding her hay and fresh-cut *Aragallus lamberti*. It was noted on August 7 that she showed no effects from the loco feeding, but on the 14th the effects began to appear. She dropped her calf on August 20. Her calf was small and weak, but was fully matured. Whether its weakness could be considered as the effect of the loco is a matter of doubt. The cow was kept in the corral and fed *Aragallus lamberti* and hay until September 17. During this time the effect of the loco poison became more and more evident. Figure 19 shows the condition of the animal on August 27. At this time the serous sac under the jaw, typical of many locoed animals, was very prominent. She was put in the loco-free pasture on September 18 and

FIG. 19.—Case 28, August 27, 1906. Cow after it has become locoed, but not a bad case. The serous sac under the chin is very prominent.

kept there with no further treatment until October 31, in order to see whether simply having good feed and being taken away from the loco might not bring about her recovery. During this time she had gained slightly in weight at first and then lost. On November 3 we commenced treating her with 15 c. c. of Fowler's solution daily. This treatment was continued until the end of the month, when she was taken to Fort Collins for further treatment during the winter. During the latter part of December she was treated with potassium iodid, but with no particularly good effect. On February 1 treatment with Fowler's solution was resumed and she received 15 c. c. daily through the month. Later the treatment was discontinued. About the middle of March she was shedding her winter coat and getting fat, and the last of March she was fat enough for beef.

This was evidently a cure, and the credit of the cure must be given to Fowler's solution. The after history of No. 28 is interesting, as she was kept during the summer of 1907 upon a pasture

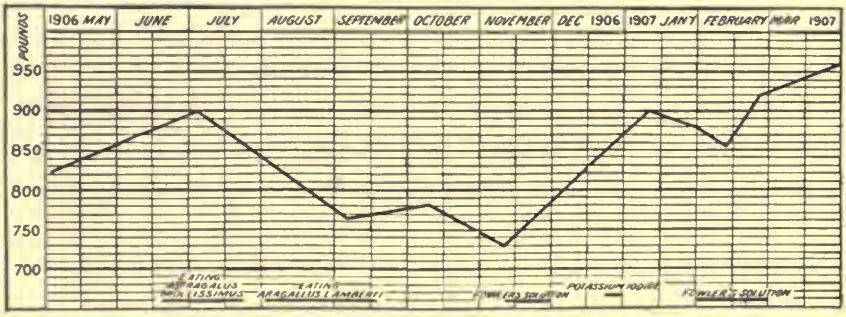


FIG. 20.—Curve of weight of cow No. 28, 1906.

where loco was very abundant and ate more or less of it through the season, but without any noticeably deleterious effects. The curves (figs. 20 and 21) show the changes in weight in the two seasons in their relation to the treatment.

RESULTS OF TREATMENT IN 1906.

In summing up the general results of the remedial measures attempted in 1906, it seemed quite clear that of all the remedies with which experiments were made success had been reached with only two—strychnin and Fowler's solution. The marked cases of cure in cattle with strychnin seemed to make it very probable that this remedy would prove useful. It also was evident from the deaths which occurred from the use of strychnin that it would be necessary to use very much smaller doses.

The results from Fowler's solution were somewhat doubtful. We have the cases of horse No. 58 and of cow No. 28, which presumably were aided in their recovery by the use of the solution.

Simply a statement of the number of cases in which there was a cure or a failure to cure would hardly give a fair idea of the results of these experiments, but in each case the individual peculiarities of the patient should be considered. As a matter of fact, in most of the cases which were subjected to treatment in 1906 the disease was very far advanced, so that the chances of cure with any course of treatment were very small. This was true in nearly all the cases of sheep and in most of the horses and cattle. The recoveries came only after a somewhat prolonged course of treatment. One of the cattle which recovered was treated forty days, another twenty-seven days. A horse which recovered on a treatment of arsenious acid was treated for thirty days. From the summer's work it seemed wise to experiment further with strychnin and arsenic,

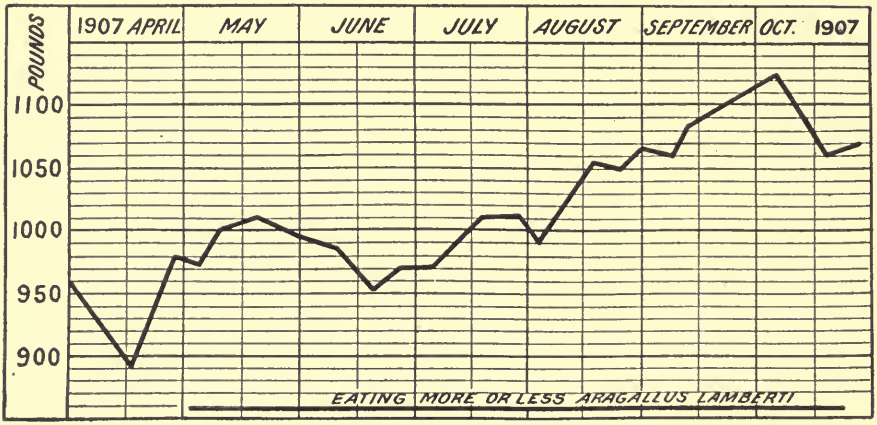


FIG. 21.—Curve of weight of cow No. 28, 1907.

using the former mainly with cattle and the latter for the most part with horses.

During the summer of 1907, then, it was determined to make as fair a trial as possible of strychnin and arsenic, using smaller doses of the strychnin. Inasmuch as some success had been obtained with arsenious acid and Fowler's solution, experiments were made with atoxyl and sodium cacodylate, it being thought that other forms of arsenic might have the same good effects. It may be remarked that the pathological lesions of locoed animals are surprisingly like those produced by the trypanosomes, and, granted that the use of atoxyl in trypanosomiasis succeeds not only because of its specific effects on the parasites but also because of its effect on the system generally, it might be possible that in atoxyl there would be a remedy also for the condition found in locoes. Sodium cacodylate was used because of the marked benefits sometimes produced in cases of anemia in human patients.

TREATMENT OF CATTLE IN 1907.

Fowler's solution.—Only one of the cattle (No. 565) was treated with Fowler's solution. It was a typical loco, although not extremely poor, and the nervous symptoms were not as pronounced as in some cases. The solution was given in 15 c. c. doses and was continued for fifty-three days. The steer gained, but quite slowly. Its weight at the beginning of treatment was 580 pounds, and when it was discharged it weighed 670 pounds. It was considered a cure, but the results of Fowler's solution did not seem to be as marked as those that were obtained with strychnin.

Atoxyl.—Atoxyl was used in three cases—Nos. 42, 546, and 558. No. 42 was one of the station animals that had eaten loco during a considerable portion of the preceding season, but did not show marked symptoms of loco poisoning. This steer was herded upon loco from the beginning of the season in 1907 until the 1st of August. As early as July 4 it was noted that the animal was holding its head low in the typical loco fashion and that the movements of its legs were somewhat nervous and jerky. A few days later the steer had the staring look in the eyes which is seen in so many locoes and the bending of the fetlock joints of the hind legs. It was kept, however, on the loco until August 1, when it was taken in for treatment. At that time the loco symptoms were very pronounced and the animal was quite weak. It was given 0.28 gram atoxyl and this amount was increased in succeeding days until a maximum of 1.4 grams was reached. This was given until September 2. When the treatment commenced, on August 2, the steer weighed 840 pounds. At the conclusion of the course of treatment the weight was 888 pounds. From that time the animal was kept in the loco-free pasture and gradually increased in weight until the end of October, when it weighed 960 pounds. Before treatment it had the typical dejected attitude of the loco and the peculiar flexing of the fetlock joints of the hind legs, but recovered so that it was bright and walked in normal fashion. This case can be considered as a cure, and the credit of the cure probably can be given to atoxyl. The curves (figs. 22 and 23) show the changes in weight in the history of the animal.

No. 546 was treated for a time with atoxyl and afterwards with strychnin, as there seemed to be no gain from the atoxyl. The gain under strychnin in this case was slight.

The third case which was treated with atoxyl (No. 558) was a bad case from the start, and probably no remedy would have succeeded in bringing the animal out.

Sodium cacodylate.—Five of the cattle were treated with sodium cacodylate, and 4 of these (Nos. 3, 6, 35, and 548) were cured. The one not cured (No. 559) was in the last stages of the disease and probably beyond any cure.

No. 35 was a cow belonging to the experiment station which had been eating *Aragallus lamberti* during the season of 1906, but did not seem to be affected by the poison. During 1907 she was herded upon loco from the first of the season and ate the weed quite freely. On July 1 she was taken in for treatment, as at this time she showed very

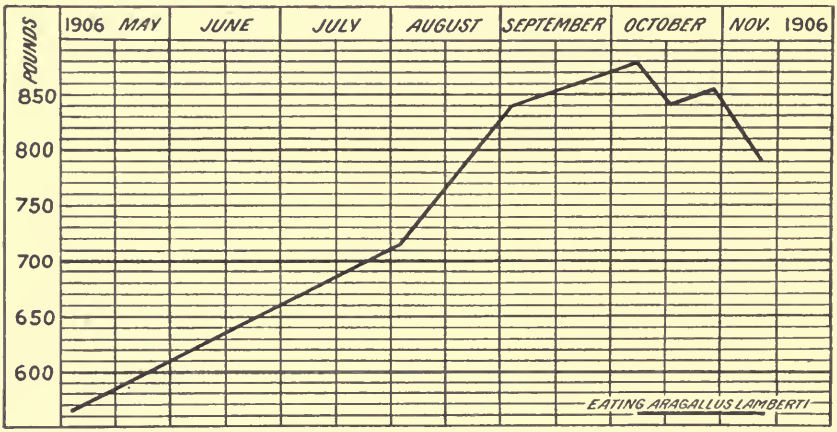


FIG. 22.—Curve of weight of steer No. 42, 1906.

distinct signs of being locoed. For a considerable time before this she had been constantly losing weight. She was given 0.6 gram of sodium cacodylate hypodermically. This treatment was continued from July 1 to August 10. Her weight just before the treatment commenced was 792½ pounds. At the time the treatment ceased she

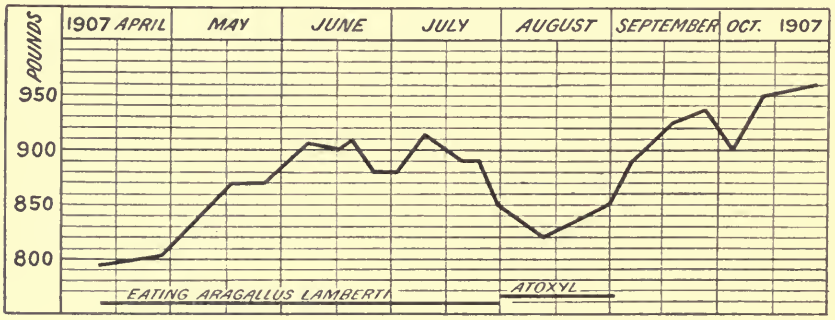


FIG. 23.—Curve of weight of steer No. 42, 1907.

weighed 882½ pounds. From this time she was kept in the loco-free pasture and at the end of October weighed 990 pounds (see fig. 24).

No. 548 was a heifer belonging to Mr. Woods, of Hugo. She was brought to the station from the Woods ranch on April 22. She was very thin and wild eyed and when eating showed in a marked way the peculiar stiff action of the jaws which is frequently characteristic

of locoed animals. She was given a few doses of magnesium sulphate and three-twentieths of a grain of strychnin was administered hypodermically from April 23 to April 27. From this date sodium cacodylate was given hypodermically in 0.3-gram doses, and the treatment was continued until May 13. The dose was increased to 0.4 gram

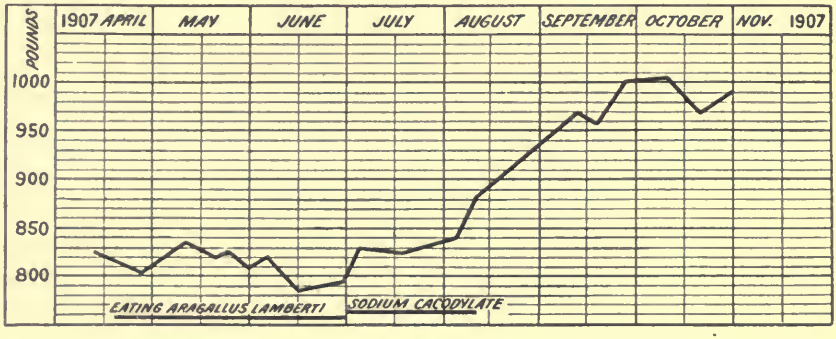


FIG. 24.—Curve of weight of cow No. 35.

from May 14 until May 31. From June 1 until June 15 daily doses of three-twentieths grain strychnin were given. On June 16 she was put in the loco-free pasture and the treatment was stopped. Her weight at the beginning of the season was 440 pounds. At the time treatment was discontinued she weighed 530 pounds and gained

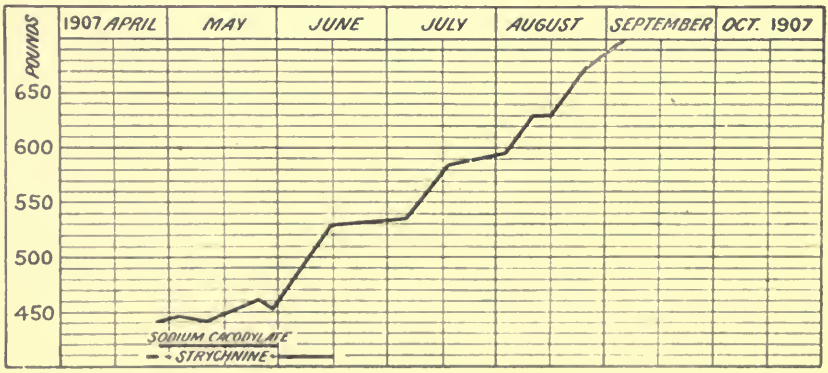


FIG. 25.—Curve of weight of heifer No. 548.

continually from that time on (see text fig. 25). She was kept in the loco-free pasture until the middle of September, when she weighed 702½ pounds. The gain of this animal was very marked and the change from a poor, worthless animal in the spring into an animal fit for beef in midsummer was very noticeable.

No. 556 was a steer received from Mr. Mosher, of Hugo. It was one of the wild locoes and very difficult to drive. It was extremely

excitable when first brought to the station. Its coat was rough and the animal was quite thin. We commenced by giving this animal three-twentieths grain strychnin doses, but this was continued for only four days, after which it was treated with one-half gram sodium cacodylate, given hypodermically. This treatment was continued from July 14 to August 23. When treatment commenced, the steer weighed 717½ pounds. At the time treatment was discontinued its weight was 810 pounds. It was kept until the middle of October, at which time it weighed 925 pounds.

Strychnin.—Fourteen head of cattle in 1907 were treated with strychnin. Of these, Nos. 503, 559, 561, and 566 died. No. 559, when received, was very poor and weak, and lived a comparatively short time. No. 566 was so weak that a few days after it was received it fell near a creek with its nose under water and was drowned. No. 561 had a complication of troubles that led to its death, although the treatment with strychnin was evidently beneficial. It gained in weight and apparently was doing better, but died, as the autopsy showed, of pericarditis.

Nine of the animals treated were distinct cures. Of these, No. 38 had been kept in the loco pasture during the months of October and November in 1906, but without showing any effect of loco poisoning. In 1907 it was herded on *Aragallus lamberti* from the beginning of the season until July 1, when it was taken in for treatment. For some little time before this it had been showing distinct loco symptoms, carrying its head low, and being slow in its movements. It showed more or less lack of muscular coordination in its limbs. A few days before this, on June 27, it had broken a horn and it became necessary to cut it off. It lost considerable blood in this operation, and this may have somewhat increased its inactivity. It was given four-twentieths grain of strychnin for five days, when the dose was reduced to three-twentieths grain. This was continued until July 31. During this time it became extremely weak—so weak that it could not be driven to the stock yards for weighing, or even taken out into the good pasture, but was kept near the house in the horse pasture. It began to pick up in about a couple of weeks, and on July 24 was taken out into the loco-free pasture with the other animals. Its weight on July 26 was 700 pounds. From July 31 it was given four-twentieths grain of strychnin daily, and this was continued until August 23, when it weighed 760 pounds. It was kept in the loco-free pasture during the remainder of the season and on November 1 weighed 875 pounds. It was then considered as entirely cured. The curve of weight is shown in text figure 26.

No. 547 was a heifer received from Mr. Woods, of Hugo. It was brought to the station April 22. It was a yearling heifer, very thin and wild eyed, and dragged its hind legs when walking, in the typical

loco fashion, and it was noticed that it ate with the stiff motion of the jaws which is peculiar to locoes. The animal was treated by administering three-twentieths grain strychnin hypodermically daily until May 14, when the dose was increased to four-twentieths grain. This treatment was continued until May 25. Besides the treatment with

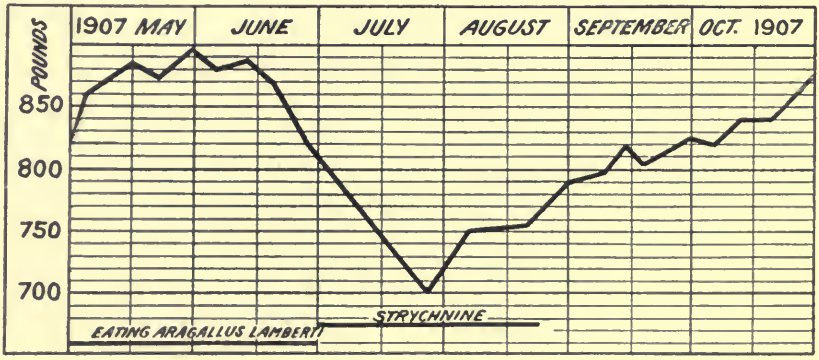


FIG. 26.—Curve of weight of steer No. 38.

strychnin the heifer was given several doses of Epsom salts in order to insure free movement of the bowels. From April 25 she was kept in the loco-free pasture until the latter part of the season. When received, she weighed 465 pounds; on May 24, when treatment was

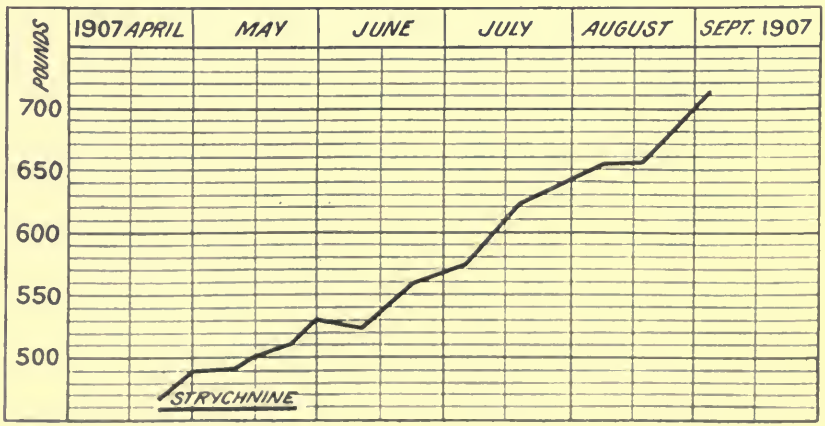


FIG. 27.—Curve of weight of heifer No. 547.

discontinued, her weight was 510 pounds, and it continued to increase until the middle of September, when she weighed 712½ pounds.

Plate XI, figures 1 and 2, show the animal's condition on April 23 and August 22. On June 4 the heifer was practically a cured animal and was in thoroughly good shape, while at the date of the last picture, August 22, she was in condition fit for market. The curve (fig. 27) shows the increase in weight.

No. 555 was a steer received from Mr. Mosher, of Hugo, on July 9. It was weak, with rough coat, in poor flesh, and quite wild. Treatment was commenced on July 10 with three-twentieths of a grain strychnin daily and continued until August 23. During this time it had gained 60 pounds. Subsequently it was kept in the loco-free pasture until it was returned to the owner about the middle of October. At that time it weighed 750 pounds and was considered a complete cure. The curve (fig. 28) shows its increase in weight.

Two other cattle were treated with strychnin. One of them, No. 68, was treated for too short a time to show any marked effects, although it was noticed that there was some improvement. The other one, No. 569, showed improvement, but had other troubles which prevented a complete cure.

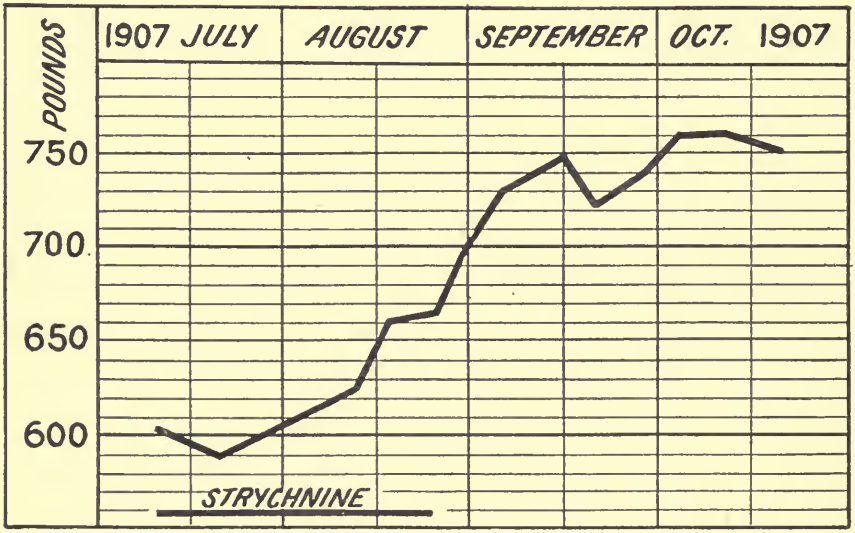


FIG. 28.—Curve of weight of steer No. 555.

TREATMENT OF HORSES IN 1907.

During the season of 1907 seven horses and one mule were treated. Strychnin was used in only one case, and in this case not only the strychnin was used, but also sodium cacodylate. It is difficult to tell just what the effect of either of these substances was upon the horse treated (No. 22). It gained during the season, but gained somewhat slowly and could not be considered as a cure.[a]

The other seven animals were treated with Fowler's solution alone. Of these, two were distinct cures, and the others with one exception all made gains. The exception was the mule. This was an old

[a] No. 22 was pastured during the season of 1908 with no further treatment and became a healthy, handsome animal.

Case 547, April 23, 1907. A heifer in an advanced stage of loco poisoning.

Case 547, August 22, 1907. Completely recovered under treatment. Heifer was sold for fat beef.

Case 551, June 14, 1907. A horse in advanced stages of loco poisoning; weight 510 pounds.

Case 551, September 20, 1907. After course of treatment; weight 825 pounds.

Case 71, June 10, 1907. A locoed sheep, emaciated and extremely nervous.

Case 71, September 22, 1907. Recovered, as a result of course of treatment.

animal, a chronic loco, and its death was due not only to the effect of the loco poisoning, but doubtless to old age. The history of two of the animals treated is of special interest and is given below.

No. 551, belonging to Mr. Mosher, of Hugo, was received May 21. It had been locoed the previous season and had been fed on grain all through the winter. Plate XI, figure 3, shows its general appearance on June 14. It was a miserable animal—was very poor, its winter coat was still on in spots, and gave it an especially woe-begone appearance. It stood about in a listless way, with its head down, but when disturbed, as by a sudden noise, it would jump and rear up, showing the unstrung condition of its nervous system. It was 4 years old and weighed 525 pounds. The case seemed almost hopeless and hardly worth experimenting with. It was put on daily doses of Fowler's solu-

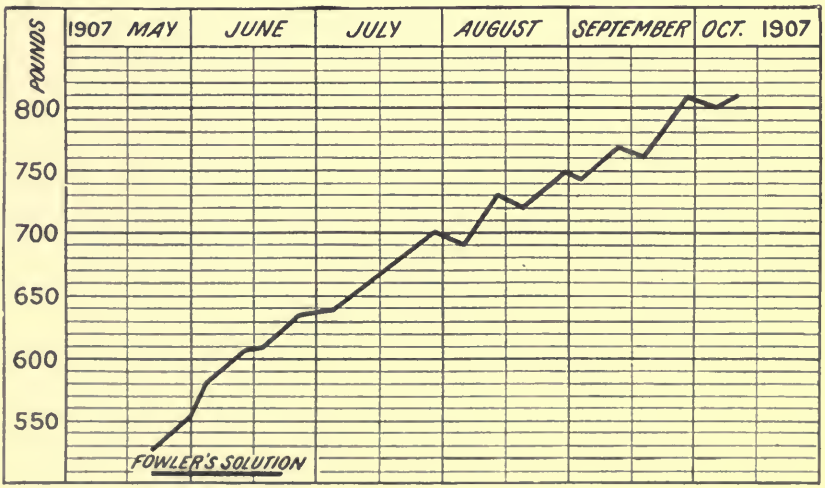


FIG. 29.—Curve of weight of horse No. 551.

tion and given some chop and oil meal daily in addition to its pasture feed. It gained rapidly. Figure 4, Plate XI, shows its appearance on September 20. The treatment was continued thirty-three days, but the animal was kept in the pasture through most of the season. In the fall it weighed 810 pounds and was a fine, sleek-looking horse. The curve (fig. 29) shows its increase in weight as the result of treatment.

No. 564 was a gelding belonging to Mr. Northrup, of Hugo. He was 7 years old, had been used as a work horse, and had been considered a gentle and valuable animal. Within two weeks preceding the time that he was brought to the station he had developed peculiar nervous symptoms—would throw himself, kick, and behave in a very erratic manner generally, so that it was considered unsafe to use him longer as a work horse. He was put on daily doses of Fowler's solu-

tion and fed a little chop each day. The treatment was continued for twenty-eight days, when he was taken by the owner and again put to work. He gave no further trouble and was later sold as a sound horse.

Of the others, No. 572 was treated for so short a time that it was impossible to say whether very much benefit was received from the treatment. It was a horse belonging to Mr. Dayton, was at the ranch only ten days, and it was difficult to say when it was discharged whether it had really made very much gain or not.

One horse was treated at Woodland Park. This animal was confined in a corral and fed chiefly upon old hay. Fowler's solution was administered in its drinking water. The horse was not under constant observation, as were the animals in Hugo, but it made steady gain under the treatment.

TREATMENT OF SHEEP IN 1907.

One sheep was treated in 1907. This was brought by Mr. Frank Hamp, and while the history of its feeding previous to the time when it was brought to the station was not known, it was pronounced by Mr. Hamp, an experienced sheepman, as a good case of loco poisoning. It was received June 10. It was in fair flesh, but in a highly nervous state. Its head was held high and shook with a peculiar vertical motion so that its teeth rattled together. It certainly deserved the name of crazy. It was put on one-twentieth grain doses of strychnin and showed marked improvement in less than two weeks. The treatment was continued for thirty-three days, when the nervous symptoms had disappeared, and it appeared all right in every way. This animal seemed to be a perfect cure. Plate XI, figures 5 and 6, show its condition when received, June 10, and when it was considered a cure, September 22.

A number of sheep that were left at the station by Mr. McIntyre and were considered locoes were kept during the season, but it was decided that none of them were cases of loco. They showed no tendency to eat the plant, would eat grass simply, and it was decided that the poor condition of the animals when received was largely the result of the presence of animal parasites. Some of them were treated for *Œstrus ovis*, and all came out in the fall in good condition without any further treatment.

PART III.—RESULTS AND CONCLUSIONS.

CAUSE OF THE DISEASE.

The first and most important question arising was to decide whether the disease was caused by the loco plants. While the results of previous investigation cast much doubt on their poisonous character, the great majority of the stockmen were agreed that the loco plants were at the bottom of the trouble. Great interest, therefore, was attached to the feeding experiments. At first it appeared that it would be shown that they were harmless. The animals placed in the loco pasture not only did not suffer from any harmful effects of the weed, but, on the other hand, grew sleek and fat. The horses fed in the corrals showed no unusual symptoms. This went on for some weeks. When the effects of the poison began to show themselves they came very suddenly, and within a short time the animals succumbed entirely. The conditions in the feeding experiments were such that the deaths of these animals must have been caused by loco. As compared with animals under conditions in other respects identical, the loco eaters invariably grew poor and eventually died. In the cases where loco was fed exclusively it may of course be said that the trouble was a lack of nutrition in the plant. This possibly might have been the case in some of the horses of the first season, but in the other cases an abundance of other feed was provided and in spite of that the animals went down.

During the second season a careful record of weights was kept and curves made to show the changes during the season. The curves show in a striking way the fact that loss of weight always followed the feeding of loco. All the horses, cattle, and sheep that ate loco in any amount were affected. No. 10 was especially interesting, because, although he ate loco, he did it in moderation, so that he lived in a comparatively fair condition, but with less than the normal increment in weight.

During the third season, too, the curves of weight showed some loss whenever any considerable amount of loco was eaten. In the summer of 1907 there was no forced feeding of loco, but the animals experimented upon were kept constantly where loco was abundant, and a daily record was kept of what was eaten by the animals when they were in the field. It was noticed that the weights varied much, according to the amount of loco eaten. No. 10 kept on in the

third summer as he had before, with the same general result, being a rather poor specimen of a steer, but not suffering largely from his bad habit.

Of the previously suggested causes of the disease other than the plants themselves, most had no reasonable basis and no discussion of them is necessary. The theory of animal parasites, however, did have a definite experimental basis. It was noticed in the beginning of our work on horses and cattle that not only was there no unusual number of parasites present in the subjects, but in many cases the number was unexpectedly small. The horses had bots, as do nearly all horses, but the number of intestinal worms was remarkably small. In many of the cattle no parasites at all were discovered. Examination of the blood gave no evidence of blood parasites.

With the sheep, however, it was a different matter. The general presence of *Œstrus ovis* and *Thysanosoma actinioides* was very noticeable. Inasmuch as the symptoms produced by *Œstrus ovis* sometimes resemble closely those of loco, a skeptical person might well question the fact of loco poisoning. Sheep, too, are erratic about their feeding, and in many cases it is a matter of some difficulty to get exact evidence of any considerable feeding upon the weed. If we not had our experience with horses and cattle before experimenting with sheep, it is very likely that we should have considered Marshall's conclusions as confirmed by our observations. But having already acquired positive evidence in regard to other animals, we were not as likely to be skeptical in regard to sheep. After some experience we could, by post-mortem examination, distinguish locoes readily, but it is very difficult before death to tell a locoed sheep from one suffering from grub in the head.

SYMPTOMS OF LOCO POISONING.

The field work has added very little new material to what had already been published in regard to the symptoms of loco disease. It appears that in some cases authors had exaggerated these symptoms and many of the recorded symptoms can not be verified, but in general they were correct.

During the early period of loco feeding there are no symptoms of poisoning. Horses and cattle will eat quite freely of the weed for a considerable period with no apparent ill effects and may even gain considerably in flesh.

The first symptoms of loco poisoning in horses are in the gait. The animal walks with a peculiarly stiff motion. It staggers as it walks, frequently moving the hind limbs with a noticeable drag, as though they were partially paralyzed. Its hind legs may be kept

far apart, as if in an attempt to support itself. In stepping over an obstacle it lifts its feet unusually high with a jerking motion, and may leap unnecessarily high, as though unable to judge of distance. It may stumble and fall, getting up with a good deal of difficulty. The animal develops a solitary habit, staying away from the rest of the bunch. This solitary habit is supposed by some to be due to its desire to hunt loco, but is probably simply because of its general nervous depression. These symptoms may appear when the animal is in fairly good flesh. It becomes slow and "dopy." It may stand for hours without eating and not go to water for days. When it attempts to drink it may have difficulty in getting its head to the water, and, when it reaches it, may move its mouth as though attempting to eat rather than with the motions of drinking. This peculiarity in drinking is accompanied by equally peculiar motions in eating and may be very pronounced before the animal deteriorates much in flesh, as shown in Plate V, figure 1.

The animal may eat little but loco, going from plant to plant hunting the weed. More commonly it eats considerable grass with the weed, but as the disease progresses it eats less and less of anything.

Sometimes a horse in the early stages of the disease will be in constant motion, walking about in a restless and aimless sort of way. If such a horse is confined in a corral, it may walk around the corral constantly, apparently never resting. As the effect of the loco increases, the animal loses flesh, its coat becomes rough, and its eyes staring. A horse in this condition will stand hour after hour the very picture of dejection, showing no interest in anything. If approached suddenly it will rear, its legs flying about in a peculiarly purposeless way, and perhaps fall over backward. This is well shown in Plate V, figures 2, 3, and 4.

A locoed horse when driven may shy violently at some little thing, and it is dangerous to use such an animal. A horse that becomes locoed after being broken may become entirely unmanageable. It is impossible to lead it, back it, or tie it. Generally speaking, however, the crazy symptoms are not so noticeable as would be supposed from the popular accounts. Nearly all locoed animals, when much affected, are constipated.

Cattle show the same symptoms, but none in so marked a way. A steer will not rear, but a sudden noise will send a tremor through its whole body, and in walking it shows the same lack of muscular coordination that is seen in the horse. From the fact that one can approach close to one of these animals without being noticed, and that then the animals will suddenly rear and jump, it is popularly thought that the eyesight is affected. It does not appear, however, that there is really any defective vision, but that the apparent trouble with the

eyes is simply due to the general disorganized condition of the nervous system. Probably the trouble is mental rather than due to any difficulty with the eyes, although this is a difficult matter to decide positively. It is sometimes difficult to lead a locoed animal into a barn, as it is apparently afraid that the door is not high enough, or it may crouch as if to avoid something that is not present at all. This is well shown in Plate VII, figures 1 and 2, where the animals in going through a gate crouch and avoid an imaginary wire or an upper bar.

Commonly, a locoed animal is dull, but under especially exciting causes it may become almost frantic. This is particularly noticeable in steers taken off the range, which will sometimes go into paroxysms of rage and attack everything in sight. It is almost impossible to drive a locoed animal. It may run into the horse of the person driving it. When started in one direction it is sometimes almost impossible to turn it. Sometimes an animal after being started will go straight ahead at a uniform gait until it strikes some obstacle. If this obstacle happens to be a wire fence it will go through it, paying no attention to incidental cuts. This would not be so surprising in the case of a steer, for cattle under normal conditions will frequently go through a fence with little harm, but most horses are afraid of barbed wire, and even a small cut will stop them. Not so with locoed horses; they will sometimes rub along a fence, mangling themselves, but apparently suffering no pain. The condition of such a horse is shown in Plate VIII, figure 6. It is evident that the nerves of sensation are partially paralyzed. It is noticeable, too, that a horse that has been cured of loco has permanently lost much of its sensitiveness. The whip and spur sometimes make very little impression, although the animal may have been very sensitive before suffering from the loco poison.

In general, the symptoms in horses and cattle are very much the same. The lack of muscular coordination is more noticeable in horses, as would be expected from their more delicate nervous organization. The head of a locoed steer or cow will shake like the hand of a palsied man. Frequently in cattle there will be local accumulations of serum, especially under the jaw. These are not so likely to occur in horses. Abortion is a common phenomenon in locoed cows. By many stockmen this loss of the calf crop is sometimes considered one of the most serious of the effects of loco. As the disease progresses, the animals eat less and less and finally die of starvation.

Another symptom which was noticed in some of the cattle was a tetanic condition of some of the flexor muscles of the hind limb, so that the fetlock joint was flexed and the animal appeared to be "standing on its toes." This is shown in Plate X, figure 5.

The symptoms in sheep are similar to those in horses and cattle, but, as would be expected from the character of the animals, they are less noticeable. The locoed sheep walks in a stiff way, staggers, and becomes weak. It lies down frequently and does not keep up with the band. Its head may shake, although this is not a very common phenomenon. The herders say that locoed sheep are "foolish" or "crazy," and these terms describe very well the general appearance of the animals. Lambs are peculiarly susceptible to the influence of the poison and may succumb to it within two or three weeks, dying with very little loss of flesh.

It will be remembered that in the list of symptoms both high and low temperatures were mentioned. The results of the field work would seem to indicate that both classes of observers were right. In some locoed animals temperatures as high as 106° or 108° F. have been observed, and in a few cases subnormal temperatures. In a great majority of chronic loco cases, however, the temperature does not differ much from the normal, and it can be safely said that chronic loco poisoning does not have any distinct effect upon the body temperature.

PATHOLOGICAL LESIONS.

Loco victims always show marked anemia. This is indicated not only by the emaciation and paleness of the flesh, but by the excess of serous fluids of the body and by the deposits of organized serum in various parts of the body. This is more especially marked at the base of the ventricle of the heart.

EXAMINATION OF BLOOD.

Inasmuch as all locoed animals show marked symptoms of general anemia, a technical study of the blood is of considerable interest. The multiplicity of general duties at the station made it impossible to make any very large number of blood determinations. Some counts, however, were made in the second and third summers and the results are significant. Little seems to have been published in regard to the blood counts of cattle, and it would have been interesting if we could have made a large number of counts of both normal and locoed animals. The counts in the summer of 1906 were made by Scientific Assistant Klugh, and his work was checked off by counts made by two other assistants. In 1907 the blood counts were made by Field Assistant Clawson, and this work was checked by counts made by two others.

The normal number of red corpuscles for cattle at our station seemed to be something over 8,000,000. This is higher than recorded normals, but our station was at an altitude of nearly 5,000 feet, and

we would expect higher counts at this elevation. The locoed animals examined in 1906 averaged 5,138,333; those examined in 1907, 21 in number, averaged 7,250,238. This apparently shows a wide discrepancy. It is largely explained, however, by the fact that those examined in 1906 were nearly all in the last stages of the disease, while most of those examined in 1907 were undergoing treatment and in some cases had already made marked gains. These results are such as would be expected, emphasizing the fact of the marked anemia. The following table is significant as indicating the effect of treatment upon locoes, as it shows in general gradual improvement as the course of treatment progressed.

Number of red corpuscles in blood of number of normal and locoed cattle, the latter in various stages of treatment.

No. of animal.	Treated less than 1 week.	Treated 1 to 4 weeks.	Treated 4 weeks and over.	Not locoed.	Remarks.
36	6,180,000				Died, bad jaw.
36		7,580,000			
38		6,000,000			Bad case.
43				8,000,000	
546			6,650,000		
546			9,600,000		
546			8,840,000		
554		9,917,000			
556		5,380,000			
556		8,900,000			
560	5,930,000				Died.
42		6,979,000			
361	7,508,000				
557			8,520,000		
558		6,120,000			
566	6,810,000				
569	6,070,000				
557			8,220,000		
35			6,473,000		
Average	6,511,600	7,268,000	8,050,000	8,000,000	

An average of 12 locoes in 1907 showed 3,735 white corpuscles.

Tests of hemoglobin were made by the Talquist scale. Healthy animals varied from 85 to 98, the average being between 90 and 95. In the locoes examined in 1906 the hemoglobin was 70, while in 1907 it averaged 85. The lowest observed in 1907 was 75 and the highest 85. It should be borne in mind, however, that many of the 1907 locoes were on the road to recovery, and in some cases were in very good condition.

On July 21, 1906, 10 healthy sheep were taken at random from a herd that were in the shearing sheds, and an examination of hemoglobin made by the Talquist method. The average of these 10 gave 87.7. On the same date an examination was made of 14 locoed sheep, giving an average of 78.

WALLS OF STOMACH.

In nearly all locoes there is a diseased condition of the stomach. In acute cases the walls are very much inflamed. In chronic cases ulcers are commonly present. The ulcers are not so common in the stomachs of horses, but are almost invariably present in the fourth stomachs of cattle. In sheep one is apt to find inflamed walls rather than ulcers.

In these ulcers a microscopic examination shows that the mucous membrance is entirely destroyed. Sometimes other parts of the alimentary canal may be inflamed, or have small ulcers, but this is not a usual condition.

HEMOLYMPH GLANDS.

The hemolymph glands are apparently much more prominent in locoes than in normal animals. This is especially noticeable in cattle. In these animals the hemolymph glands seem to be very numerous in the thoracic cavities, in the connective tissue about the heart, and in that in front of the thoracic aorta. They are only less noticeable in the lumbar region of the abdominal cavity. In the literature on the hemolymph glands there seems to be nothing in regard to the question as to whether numbers of these glands have any pathological significance. Most of the investigations have been directed to physiological questions. There has been no opportunity for the author to make the extended observations which would be necessary to throw light on this question. Preliminary observations on a considerable number of animals in slaughterhouses make it seem probable, however, that the normal number is much smaller than in the case of locoes, and it seems possible that the condition of chronic anemia in these poisoned animals may be correlated with the number of hemolymph glands.

NERVOUS SYSTEM.

The central nervous system is generally in a hyperemic or congested condition. In a few cases clots were found in the lateral ventricles of the brain. We have never, however, found clots in the fourth ventricle, although this has repeatedly been said to have been the case by the earlier observers of loco phenomena.

The serous exudate in the epidural space is especially abundant and is more or less organized. Commonly it is particularly abundant about the points of exit of the spinal nerves. This condition is rarely absent in chronic locoes. It seems probable that the pressure of this

coagulated serum may be the cause of many of the nervous symptoms which are pronounced in loco victims. In some cases this coagulated serum is especially abundant in the lumbar region, and it might well be the cause of the partial paralysis of the hind limbs, which is frequently very marked.

In locoed cows and mares, generally speaking, the ovaries are found to be more or less diseased. They are generally small and hard, and frequently contain serous cysts.[a]

In a number of cases it was found that the kidneys were somewhat diseased. This was not, however, the condition of the majority of the cases, and would not seem to be typical of loco poisoning.

VIRULENCE OF LOCO POISON.

TIME REQUIRED TO PRODUCE POISONING.

Previous authors vary greatly in regard to the length of time taken for loco to affect animals. Some say that it takes only a few days; others that the poison may be several years in producing marked effects. Our work seems to show that small amounts of the weed produce no appreciable effect, and that the poison is cumulative, so that the apparent results come quite suddenly after a period when the animal does not appear to be affected at all. The time from the beginning of the feeding to death in the animals experimented upon varied from two months and eight days to six months and nine days. It might be expected that there would be much variation in the time, because it is impossible to secure uniformity in conditions. There is a great difference in the individual susceptibility to the poison, and when animals are in the pasture some eat a very much larger amount of the loco than do others. When fed in the corral, too, on a mixture of loco and other feed, there will be an individual difference in the relative amount of loco eaten. Of the 1905 cattle dying of loco, the average length of life after the feeding was begun was five months and six days. Of these, No. 12, which was fed partly in the corral, died in three months and thirteen days. Of the other four, two died in six months and five days, and one in six months and four days. This would seem to indicate that the corral-fed animals succumbed the more quickly. In this, as in other cases, we must bear in mind, however, that while doubtless the corral-fed animals ate more loco, they may also have suffered somewhat from confinement and from an actual lack of proper food. This doubtless was true in the case of

[a] Dr. John R. Mohler, chief of the Pathological Division of the Bureau of Animal Industry, calls attention to the fact that a cystic condition of the ovaries is a common condition in the horses and cattle of the West, and that this condition may not be due to the specific effect of the loco poison.

some of the animals of the first year. Then, too, generally speaking, when animals were first taken into the corral they were starved to give them an appetite for loco. In other cases some were fed loco exclusively for many days. This treatment doubtless would occasion considerable losses.

Of the 1905 horses the average length of life after commencing to eat loco was three months and seventeen days; those eating *Aragallus lamberti* lived three months and nineteen days; those eating *Astragalus mollissimus* lived two months and ten days.

In 1906 cattle lived on the average three months and seventeen days; the corral-fed lived three months and four days; the pasture-fed lived three months and seventeen days. The horses lived four months and nineteen days; the horses eating *Aragallus lamberti* lived four months and twenty-four days; those eating *Astragalus mollissimus* lived three months and fourteen days. Those in the *Aragallus lamberti* pasture lived four months and twenty-eight days; those fed on *Aragallus lamberti* in corral lived four months and twelve days.

It will thus be seen that in the first year the horses died sooner than the cattle, while in the second year the cattle lived the shorter time. This difference in results I will not attempt to explain fully. It may be said, however, that in the season of 1905 more of the horses than of the cattle were fed in the corral, and doubtless they suffered more from shortness of feed, especially as some of them were for a time fed on loco exclusively. In the season of 1906 one of the cattle had eaten loco during the latter part of the preceding season, but this time was not taken into account in the tabulation of the averages. This reduced the average of the cattle somewhat. Then there is reason to think that some of the second season's cattle were peculiarly susceptible to the poison. The cattle during the second season ate much more freely of the weed than did the horses. It must be recognized that the number of our cases is not large enough so that we can place implicit reliance on averages. All we can say is that the results are significant, but must be interpreted very carefully.

The animals eating *Astragalus mollissimus* died more quickly than those eating *Aragallus lamberti*. Of the horses of 1905, those eating *Aragallus lamberti* died in three months and nineteen days; those eating *Astragalus mollissimus* in two months and ten days. Of the horses of 1906, the one that was fed *Astragalus mollissimus* died in three months and fourteen days, while those eating *Aragallus lamberti* died in four months and twenty-four days.

The work upon sheep was of such a character that no general conclusions can be drawn as to the length of time for the poison to take effect.

Horses and cattle feeding freely and continuously upon *Aragallus lamberti* may live from three to six months. Horses feeding freely and continuously upon *Astragalus mollissimus* are not likely to survive longer than from two to four months. The fatal issue of the habit may be put off almost indefinitely, however, in the case of the moderate eater. It may live a year or several years, but it greatly deteriorates.

During the third season none of the animals were fed in the corral, but all were kept in a pasture where they had an abundance of grass, and they were not forced upon the loco except that they were held a part of the time where loco was abundant. As soon as they showed evident symptoms of being poisoned they were taken up for treatment instead of being permitted to go through the whole course of the loco disease, as in preceding seasons. An attempt was made to preserve life as long as possible and to produce cures when practicable. The natural result of these conditions was that the animals yielded to the poison much more slowly than in the preceding season. Another fact had, doubtless, some influence, namely, that the animals were in most cases the survivors of preceding experiments and were originally more or less immune to the effects of the loco.

AMOUNT OF LOCO NECESSARY TO PRODUCE POISONING.

The limitations of the field work and the comparatively small number of animals experimented upon make it impossible to state with any definiteness how much loco an animal must eat before showing symptoms of the poison. In all cases some pasture feeding was given to the animals kept in the corrals in order to give them suitably healthful conditions of life. When in the pasture, some would eat loco in considerable abundance, while others would devote themselves wholly or in a very large part to grass. It was our custom to put these animals into pasture at least one day in the week. It is to be presumed, too, that the amount of hay eaten while they were in the corrals would make some difference in the effect of the poison, and thus bring in wide individual variations.

Because of the small number of animals it was possible to subject only a few to a single line of treatment. In most cases each animal was a subject of several phases of the experiment. The amount of loco fed in the corrals, however, was weighed and a record kept for each animal. From these records we can make a rough estimate of the amount eaten before the symptoms of loco became evident. From these records it appears that about 400 pounds of *Aragallus lamberti* will loco the average horse or steer.

RELATIVE IMPORTANCE OF ASTRAGALUS MOLLISSIMUS AND ARAGALLUS LAMBERTI.

The tentative conclusions reached at the end of the first year in regard to the effects of *Aragallus lamberti* and *Astragalus mollissimus* were amply confirmed by the work of the second and third years. *Astragalus mollissimus* is harmful only to horses. The loss of cattle from this plant is inconsiderable. This is not because the cattle can not be affected by the poison, but because they do not eat the weed. It was found in the corral experiments almost impossible to make cattle eat this species even when they were starved to it. Generally they would starve to death rather than take to it. So far as our experiments went, it may be said that cattle never eat *Astragalus mollissimus*. In regions where this weed prevails, and not *Aragallus lamberti*, locoed cattle are almost unknown. Examples of this are the regions about Holyoke, Colo., and Imperial, Nebr. The same thing is reported in the *Astragalus mollissimus* region in the Panhandle of Texas. About Santa Rosa, N. Mex., where the damage is commonly ascribed to *Astragalus mollissimus*, it is true, the author was told that possibly 10 per cent of the cattle and 50 per cent of the horses were lost annually. It would appear that perhaps *Astragalus mollissimus* was responsible for the loss of the cattle in this locality. The locoes of this neighborhood, however, have not been examined with any care, and it is possible that plants other than *Astragalus mollissimus* are responsible for the cattle loss. Our experience showed that not only would the cattle not eat *Astragalus mollissimus*, but that horses were not likely to take to it except because of scarcity of other food.

It is very different with *Aragallus lamberti;* not only horses, but also cattle and sheep, eat this readily. They are more likely to eat it during a scarcity of other food, but they will not only continue to eat it when other food is abundant, but may begin the habit at any time of the year. Of course they are more likely to start eating the loco in the winter and early spring and in the fall when the loco is green and succulent and the grass is dry. But even in midsummer, when supplied with abundant pasturage, if thrown in contact with loco plants they may eat considerable amounts—enough, even, to produce fatal results. Cattle eat *Aragallus lamberti* much more readily than do horses. Nearly all cattle will eat it more or less, and a large proportion will contract the habit. A great many horses, on the other hand, will not touch it even if run upon ranges covered with the weed. Consequently the loss of cattle from *Aragallus lamberti* is much greater than that of the horses.

Sheep, too, eat *Aragallus lamberti* very readily. It is always considered a misfortune to have a few sheep commence eating the weed,

for sheep are such imitative creatures that a few may lead a whole band astray. Some sheepmen immediately cut the throats of loco eaters on this account.

The symptoms of poisoning from *Aragallus lamberti* are like those from *Astragalus mollissimus*, but the effect does not come so quickly. The laboratory work conducted by Doctor Crawford has established the fact of the greater toxicity of *Astragalus mollissimus*. However, vastly the greater amount of damage is done by *Aragallus lamberti* because it is eaten so much more readily, and because it affects cattle and sheep as well as horses. Our pasture experiments all go to show that most horses when kept where *Aragallus lamberti* is abundant will sooner or later yield to the poison, and that the cattle succumb much more quickly to the attractions of the weed.

SUSCEPTIBILITY OF DIFFERENT BREEDS.

Sheepmen are unanimous in saying that the blackfaces are much more susceptible than the Merinos. This statement was abundantly confirmed by our observations.

In regard to cattle and horses, it is a matter of common observation among stockmen that the better bred animals are more likely to become locoed. They explained this in part, and probably reasonably, by the fact that animals accustomed to be taken care of do not know how to "rustle," and consequently take the food that comes first instead of hunting for better material. Reliable stockmen tell me that Durhams are more easily affected than Herefords. When our experiments started in Hugo, an old stockman remarked that two black steers in our herd would be the first to be affected, saying that this would be true not because of their color but because they were of better blood. The result showed the accuracy of his prophecy, for the black ones were the first to succumb. While we had a number of different breeds among our experimental animals, the numbers were not large enough for any general conclusions to be drawn. The experiments would indicate, however, that Herefords are decidedly less susceptible than Aberdeen-Angus cattle. The one steer of our herd that refused to eat any considerable amount of the loco was a scrub. In Colorado generally I saw more locoed Herefords than of any other breed, but this is doubtless explained by the fact that this is the most popular breed of range cattle.

AGE SUSCEPTIBILITY.

Marshall (1904) states that loco poisoning appears only in young sheep, generally speaking; never in those over 2 years old. Blankinship (1903) states that only young sheep and colts are affected. Older sheep and horses rarely acquire the habit. Our experiments

in Colorado show that while lambs suffer in an acute way from loco, the older sheep are by no means free from the disease.

In cattle and horses we had a general impression of the greater susceptibility of the younger ones, but this was hardly borne out by the facts. There seemed to be very little difference in the time taken to kill, whether the animals were young or old. We could determine but little about this in the first season's work, for most of the stock were young animals. During the second and third seasons, however, we had a number of old animals, especially among the horses, and there was no clear-cut difference in susceptibility to the poison because of difference of age. As is intimated elsewhere, there is a difference in individual susceptibility which must always be taken into account.

The apparently greater susceptibility of young animals, as noticed by other observers, may be due in part to the fact that there are more young animals than older ones, and hence apparently a greater number of cases among the young animals, and partly to the fact that many of the old animals are those that have survived because of an individual lack of susceptibility to the temptations of the plant.

EFFECT ON ANIMALS OTHER THAN HORSES, CATTLE, AND SHEEP.

We found it very difficult to get evidence of the effect of loco on mules. Some stockmen reported that they had seen locoed mules, while others said that mules were not affected. Considerable interest, therefore, attached to observations of the two mules which formed a part of our experiment in 1906. Unfortunately, both were old animals, and the poorest one died of old age. The other, however, was a fairly healthy animal and its death proved conclusively that mules could be locoed.

In the summer of 1907 a locoed mule was brought in to the station for treatment. It had the typical symptoms of loco poison. Its insensibility to barbed-wire fence cuts was especially marked, for it would run against a fence and rub itself along for two or three lengths, the wire cutting through the skin and into the muscle, but apparently occasioning no pain. When started up in the pasture it would trot along at a slow gait in almost a straight line, going for a long distance, sometimes until some obstruction in its way would stop it. This was an old animal, and while it would eat fairly well and we found it possible to dose it, it succumbed, probably from the combined influence of old age and the loco poison. There seems no longer any question in regard to the possibility of mules becoming locoed by eating *Aragallus lamberti*. It does not appear, however, that they are as liable to take to the plant as are horses.

In regard to other domestic animals and wild animals, the testimony is conflicting, and it is impossible now, with the evidence at hand, to pass on it. Some stockmen say that they have seen locoed antelopes. Others say that antelopes are not affected. Inasmuch, however, as there is no record of feeding experiments on antelopes, we must consider the matter as still an open question. Doctor Crawford's pharmacological work shows that rabbits are affected, and it must be presumed that other herbivorous animals may be susceptible to the poison of the weed. One reputable stockman told me of a man who fed cut loco to a lot of pigs, thinking it would be good for them, and locoed them all. The writer has even heard of locoed hens.

EFFECT ON MAN.

There are many stories of men poisoned from eating loco, but none of these can be authenticated. As a matter of fact, inasmuch as our work on horses, cattle, and sheep shows that the poison is very slow in taking effect and that an animal can eat the weed for quite a long time without any apparent harmful results, it seems unlikely that men have eaten enough to show the results of the poison. Pilgrim in 1898 investigated a case which was brought into the Hudson River State Hospital, and concluded that the cause was syphilis. The story by Janvier in Scribner's Magazine, Volume I, page 67, entitled "In Mexico," which is frequently quoted in this connection, was based on the properties not of the loco plant, but of stramonium.

LOSSES FROM LOCO POISONING.

Attempts have been made to get some estimate of the losses from loco poisoning, but it is impossible to make more than the rudest kind of conjecture. An intelligent horseman near Wray, Colo., estimated in 1905 a loss of 3 per cent of the horses. One man near Holyoke in 1906 lost from 12 to 20 per cent of the horses in one herd; another in the same locality in 1905 lost practically all his horses. The winter of 1906 was especially disastrous in New Mexico and Arizona. One man in the Estancia Valley in New Mexico lost 50 per cent of his horses. A conservative stockman near Santa Rosa, N. Mex., estimated that during one winter 50 per cent of the horses and 10 per cent of the cattle perished. Around Jerome Junction, Ariz., the estimated loss in the winter of 1906 was from 30 to 60 per cent, and correspondingly large losses were said to have taken place about Flagstaff, Ariz. Blankinship says that in some parts of Montana the loss of lambs reaches as high as 50 per cent. It has been estimated that the annual money loss in Colorado is between $1,000,000 and $2,000,000.

The death loss, however, may not be the largest factor in the account. The loss from deterioration of stock and from premature sales is very heavy. Many stockmen, when their herds commence to eat loco, sell out rather than run the risk of having a lot of locoed animals on their hands, and this loss means a very large reduction in their profits. This, of course, is a loss that it is impossible to make any estimate of. In many cases stockmen have been driven out of the business by the weed, and have even gone into bankruptcy. In some sections of Colorado, I am told, there are not more than one-fifth of the animals on the range that were found a few years ago, and this reduction of numbers is entirely on account of the loco. When it is remembered that these losses occur more or less widely through the semiarid region from the Canadian Provinces to Mexico, it will be seen that the total loss from these plants is extremely large.

DESTRUCTION OF LOCO WEEDS.

The question is naturally raised as to whether some means can not be devised of exterminating loco weeds from the range. The most obvious way of doing this is by cutting them out. This is entirely feasible if the land is worth the price of the work. There is an erroneous idea among many of the stockmen that plants will grow from any part of the root, and that cutting the plants is useless unless the whole root is dug up. While the plant is a perennial, the buds are all at the crown, and if this is cut off the plant is destroyed. This is brought out by Professor Blankinship very clearly in his paper of 1906. Actual experiments in Hugo in connection with our loco work there have proved the correctness of this view. Inasmuch as all the seeds do not germinate the first year, of course it is necessary to repeat the cutting in successive years, but that it is entirely possible to clear pastures of the loco there is no doubt.

Doubtless much can be accomplished by the use of a mowing machine at the time of flowering. The flower scapes of *Aragallus lamberti* are erect and a machine would cut out most of them and thus spoil the seed crop. The work of cutting out, however, is not as laborious as one might think, and it is very effective.

At the present time the most efficient way of combating the loco seems to be to cut it out. Where pastures are fenced in this can be done very easily. *Astragalus mollissimus* is much more easily cut out than *Aragallus lamberti*, as it grows in patches and rarely in any very large amount. On the open range, of course, this method of exterminating the loco is impracticable.

In many cases much can be accomplished by keeping animals away from ranges covered with loco during the time when feed is

short, inasmuch as they are much more likely to contract the habit when other food is lacking. Sometimes it may be profitable to feed for a short time, in order that the habit may not be formed.

The question was raised whether it might not be possible to kill out the loco plants by chemical means, that is, to use some substance that would kill the loco without injuring the grass. Although the prospect was not very hopeful, it seemed worth while to try the experiment. Plots of land were laid out with suitable control plots, and experiments were made by sprinkling with varying strengths of ammonium sulphate, copper sulphate, and iron sulphate. From the use of ammonium sulphate and copper sulphate there were no good results; if anything the loco seemed to grow more luxuriantly. It at first appeared that certain strengths of copperas were giving the desired results; the leaves of the loco were killed while the grasses were uninjured. The thing appeared so hopeful that an experiment on a larger scale was attempted, and a considerable patch of ground on the ranch of Mr. McIntyre, near Hugo, was treated in the fall and left over winter, and then treated again in the spring. It was thought that by this extended treatment it would be possible to determine whether the poisoning was effective or not. The result was, however, disappointing, and it was evident that these substances could not be relied upon as exterminators of the plant.

INSECTS DESTROYING LOCO PLANTS.[a]

A large number of more or less destructive insects are found in the loco plants. Of this number the larvæ of *Walshia amorphella*, a small moth, and those of *Euxesta notata*, a minute fly, are especially active. They not only bore in the roots, but ascend into the leaf stems and flower scapes, and when very abundant kill large numbers of the plants. In 1905 it was noticed than an especially luxuriant loco pasture, where the *Astragalus mollissimus* grew in large bunches over a considerable area, was practically cleared of the plants in less than a month's time, and during the remainder of the season and through the summers of 1906 and 1907 very few plants were found there. All along the line of the southern branch of the Union Pacific Railroad in 1906 and 1907 there was a general destruction of *Astragalus mollissimus*. There were few large plants, most of those found being small, and in many cases they died early in the season. It is noticed, too, that these larvæ work so early in the season as very largely to kill the plants before the seeds are matured.

[a] The insects mentioned under this heading have been identified by Dr. F. H. Chittenden, of the Bureau of Entomology of the United States Department of Agriculture, and a paper on the insects known to infest the loco weeds has been published as Bulletin 64, Part V, new series, of that Bureau (pages 33–42).

From conversations with observant stockmen it appears that *Astragalus mollissimus* comes and goes in cycles. Probably the insects increase to such an extent as to destroy the loco; then, because food is lacking, the insects largely die out, only to reappear again when the loco gets another good start.

The same larvæ live in *Aragallus lamberti*, but never seem to do so destructive work in this plant.

The question naturally arises whether these insects can not be encouraged and carried from place to place in order to exterminate the loco plants in other areas. In the summer of 1906 the question of colonizing the insects was raised in connection with our experimental work, but it was hardly deemed practicable. An examination of the more luxuriant loco pastures of western Nebraska showed that the insects were already there, and were likely to increase as rapidly as they would if we lent any additional aid. It appears probable from our observations in Colorado that the insects, at the present time, have put in their work so effectively that *Astragalus mollissimus* is likely to be not, perhaps, a rare plant, but very much reduced in numbers for possibly from two to five years.

The grub of *Cleonus quadrilineata* is especially destructive to *Aragallus lamberti*. A. B. Clawson, field assistant in 1907, spent considerable time in studying the work of this insect, and while his work is necessarily incomplete it is sufficient to indicate that this is one of the most important factors in keeping down the numbers of the *Aragallus lamberti* plants. The larva of this beetle when mature is very noticeable when one digs up the plants of *Aragallus lamberti* by the roots. It is a large white grub, and either lives in the roots or, in many cases, burrows in the outside of the root of the plants. It was found in abundance as early as the latter part of June. Perhaps more were found working upon the surface of the root, but in many cases they worked inside and destroyed a large part of the root of the older plants. It was noticed about the end of the first week in July that the pupæ were being found in the cases. These cases were apparently made largely of dirt and are commonly found on the side of the root, partly occupying spaces which had been eaten out by the grub. The cases are about 20 to 25 mm. long by perhaps half that in width, being irregularly oval in shape.

The first adult beetles were noticed coming from the pupal cases toward the end of July. At this time and during the first part of August the adults were quite fairly abundant. Just how much damage these grubs do to *Aragallus lamberti* it is difficult to say. Certainly they do not kill out the plants so thoroughly as those insects which infest *Astragalus mollissimus*. Their main work seems to be confined to the older plants, and, without any question, they hasten the death of these plants. In some pastures where the *Aragallus lamberti* had

grown into unusually large plants, it was noticed that they were all being destroyed. The chief work of the larva seems to be in limiting the number of years during which the plants may live.

It should be noted in this connection that the most destructive work of this insect comes after the period of flowering and seed formation, so that even when plants are killed they have already produced the annual crop of seed.

EFFECT OF DRY SEASONS.

It is a matter of common remark among stockmen that the loco weeds are most abundant in wet seasons. This is, doubtless, because the seeds have a water-resisting coat and do not germinate except under favorable conditions. Experimental attempts to raise loco weeds have shown this to be the case. Mr. V. K. Chesnut tells me that in Montana it was three years before they had a crop from sowing the seeds. Our own experiments gave similar results. It is not known how long the seeds will remain viable, but it is certainly several years.

During the past dry seasons in Colorado the loco plants have almost disappeared in some sections, this being probably due to the combined influence of insects and meteorological conditions. The insects have destroyed the old plants, and because of lack of favorable conditions for germination, new ones have not come in to take their place.

REMEDIES.

From the characteristics of the loco disease and its diagnosis, it is seen that it is the result of long-continued feeding. In most cases the amount of the plant eaten at any one time is small, much more being eaten of the grasses than of the loco. The effects of the poison in the more acute cases do not appear under about two weeks, and in most of the adults only after weeks and even months of feeding. Only very small doses of the poison are taken at any one time. When an animal is finally locoed it may be assumed that there is very little of the poison in its system in a form to be reached by an antidote. While doubtless an antidote for the poison may be found, it is not practicable to use the antidote as a remedy for chronic cases. In cases of acute poisoning an antidote can be used, but in the slow chronic cases it would be useless to attempt any such thing. It would seem possible, however, by the use of an antidote to prevent the original effects of the poison. Naturally the question arises as to whether it may not be possible to immunize the animals by small doses. From what has just been said it is evident that this is impossible in a poison of this character.

In the way of remedies, from a medical standpoint, there would seem to be three things to be attempted: First, to give something

that would destroy the appetite for loco; second, to give an antidote to counteract the effects of the poison; and, third, to give such remedies as would counteract the general effect of the poison and aid the animal in recovery. The chances of finding a substance that in one or a few doses would destroy the appetite for loco are not very great. Some attempts were made in this line, but, as perhaps might have been expected, were unsuccessful. Doctor Crawford's report on the finding of barium in the plants was made so late that no experimentation in regard to an antidote for this substance was possible, and this part of the work will have to be taken up later.

It seemed more hopeful to make the attempt to give remedies for the general condition of the animals with the hope of aiding them in building up against the effects of the poison. As has been indicated in the diagnosis, the chief effect of the poison is on the central nervous system, and this results not only in the marked nervous phenomena, but in anemia and general debility. In seeking a remedy, then, it seemed desirable not to attempt to use an antidote for the poison, but to use such remedies as would affect the nervous system and aid the animal in getting out of the anemic condition which is so pronounced. All the remedies tried had this end in view—to build up the patient with especial reference to the nervous system.

Some attempts at remedial measures were made in 1906. In the summer of 1907 this work was prosecuted more vigorously on the lines which were indicated by the results of the previous summer. Inasmuch as most chronic cases of loco are constipated, in all of the treatment we made sure that there was free action of the bowels. This was secured by occasional doses of Epsom salts, the condition of the animals being watched from day to day. During the summer of 1907 especial attention, too, was paid to the diet. All animals under treatment were fed a little grain daily. With this was mixed a little oil meal because of its laxative properties. When it was necessary to feed hay, alfalfa was used, largely because it also is laxative.

The remedies experimented with in 1906 were strychnin, potassium iodid, asafetida, caffein, arsenious acid, Fowler's solution, and valerian. As the result of this work we felt convinced that asafetida, valerian, caffein, and potassium iodid gave no good effects. In the use of strychnin the results were a little doubtful. Two of the cattle were cured during the strychnin treatment and there seemed no good reason why this drug should not have the credit of the cure, but it was true that other animals treated with strychnin died, in some cases partly at least as the result of the poison. None of the horses showed improvement from the use of strychnin. The fact that several of the animals showed indications of poisoning made it probable that strychnin was administered in too large doses, although only the minimum doses of the ordinary veterinary materia medica were used. It seemed probable that locoed animals were, perhaps, more

sensitive to the effects of strychnin and should be treated in especially small doses.

Arsenious acid effected a cure in one of the horses. This animal was treated at the Colorado Agricultural Experiment Station during the winter of 1906–7 under the general direction of Doctor Glover, and, while it was a clear-cut case of loco disease in the fall of 1906, with all the typical symptoms, it came out in the spring definitely and apparently permanently cured. This animal was used as a saddle horse during the summer of 1907 and at no time showed any of the signs of loco poison, if we except a slight loss of spirits.

One of the cattle, too, after it was treated with Fowler's solution was completely cured.

TREATMENT OF CATTLE IN 1907.

Fowler's solution.—Only one animal was treated with Fowler's solution in 1907. This steer was cured, but the cure was much slower than in some of the other remedies, although the subject was a favorable one.

Atoxyl.—One steer was treated with atoxyl and recovered. Two others did not do well and were afterwards put on strychnin and improved. The results from the use of atoxyl were not considered favorable.

Sodium cacodylate.—Five cattle were treated with sodium cacodylate. Of these 1 died, 1 improved, and 3 were cured. The one that died was an especially bad case and nearly hopeless from the start. The net result from the use of sodium cacodylate was very favorable.

Strychnin.—Fourteen head of locoed cattle were treated with strychnin. Two of these were of the experiment stock, while the others were brought in from ranches in the neighborhood for treatment. Of these 14, 2 showed improvement, 3 died, and 9 were cured. Of those that died one was very much improved so far as the loco poison was concerned, but died of pericarditis. The other two were very bad cases and one of them died by drowning, being too weak to get up after falling with its nose under water. One was treated with strychnin followed by sodium cacodylate, followed by another course of strychnin, being treated in all fifty-one days, and was discharged cured.

Strychnin and sodium cacodylate.—Two were treated with strychnin and sodium cacodylate at the same time and were cured.

TREATMENT OF HORSES IN 1907.

Seven horses and 1 mule were under treatment in 1907. In all these cases Fowler's solution was used, but one was also treated with strychnin and sodium cacodylate. No good results appeared from the use of the strychnin and sodium cacodylate. The mule died. It

was an old animal and a chronic loco, and the combination of troubles carried it off in spite of treatment. Old age without any doubt was an important factor in causing its death. Two of the others were not treated long enough for final results, but gave promise of recovery. Two showed distinct gain, but were not considered as positively cured. Two were distinctly cured.

GENERAL RESULTS OF TREATMENT.

RESULTS WITH CATTLE.

A careful study of the cases of cattle which were treated in the two summers leads to these conclusions:

1. Very advanced cases are generally hopeless; occasionally they may be cured, but ordinarily they will die.
2. Cattle may recover without any treatment if they are taken from loco and put upon good feed. There was one marked case of this kind in our herd in the summer of 1907.
3. Atoxyl is not effective as a remedy.
4. Fowler's solution is of doubtful efficacy.
5. Good results almost invariably follow the use of sodium cacodylate or strychnin, or the two used together. We felt the most certain of good results under the strychnin treatment. This opinion was reached partly as the result of a statistical study of the cases and partly as the result of the general impression made upon us in the course of treatment. Whenever, during the summer, we were particularly anxious that a given animal should recover, our tendency was always to put it upon the strychnin treatment.

RESULTS WITH HORSES.

The net result of the work of the two summers on horses shows:

1. As in cattle, advanced cases are hopeless.
2. As in cattle, recovery is possible in mild cases without treatment.
3. Strychnin does not give good results.
4. Fowler's solution can be used with the expectation of beneficial results.

PERMANENCY OF LOCO CURES.

It must not be supposed that an animal cured of loco will never eat the weed again. Probably in most cases if they have an opportunity they will go back to their old habits. When a horse has been cured it should be kept in a pasture free from loco. When a steer has been cured, it is probably best to put him upon the market as soon as he is in sufficiently good flesh rather than to run any risk of a second period of loco poisoning. It is rather interesting in this connection, however, that the two head of cattle which were cured in 1906 and were pastured on loco in 1907 continued in the loco pasture the whole

season, eating more or less of the weed, probably rather less, and showed little effect. It seems rather probable than in many of the cured cases they are not as likely to go back to eating loco as are animals that have never been subjected to its temptations before.

PREVENTION OF LOCO POISONING.

Not all animals will contract the loco habit, and those that do so will ordinarily commence the eating at a time when feed is short. It is a matter of common knowledge among stockmen that it is during the winter and spring seasons that animals are most likely to commence eating the loco weeds. This is especially noticeable in the spring, when the grass of the preceding season has been largely grazed off and the new grass has not started. At this time the loco weeds are, in ordinary seasons, green and attractive, and are frequently the most prominent plants in the plains vegetation. Thus many animals, forced by hunger, commence to eat the weeds, and while some of them abandon the loco after the grass starts, others contract the habit, which continues even after there is an abundance of good feed, and leads eventually to their death.

Much can be accomplished by the stockmen at this season in the way of prevention. In localities where the loco is largely confined to definite areas of the range it is possible to keep the animals away from the loco until after the grass has started, when there is likely to be very little trouble. In some cases feeding for a short period will bridge over the dangerous time, and while it may seem somewhat expensive to feed, it is evidently better than to have the stock die.

SUMMARY OF WORK ON REMEDIES.[a]

1. Some locoed animals will recover if taken from the weed and fed well, without any treatment.

2. Most locoed animals will recover if they are taken from loco, fed carefully, and treated on the lines indicated by our experiments.

3. In all cases care should be taken to relieve constipation, either through the character of the food or by the use of magnesium sulphate.

4. Horses are best treated with Fowler's solution in daily doses of 15 c. c., continued for at least one month.

5. Cattle are best treated with daily doses of strychnin, the doses not exceeding three-twentieths of a grain, given hypodermically, and continued for one or two months. It is especially important that the dose should be small, as locoes are very susceptible to the bad effects from overdosing.

[a] Further work on remedies during the summer season of 1908 confirmed the conclusions of the preceding years.

GENERAL SUMMARY.

For many years complaints have been made of the losses of cattle, horses, and stock in the semiarid region of the West from a disease which is popularly known as "loco," this name being given because of the crazy symptoms of the affected animals. The disease is prevalent from the Canadian provinces on the north to Mexico on the south, and the losses have been very great; so great, in fact, that in some sections stockmen have been thrown into bankruptcy, and sometimes most of the animals have been taken off the range. Some years ago the State of Colorado created a bounty for cut and dried loco, but such a large amount of it was collected and the bounty payments amounted to such large sums that the law was repealed for fear that the whole State would be thrown into bankruptcy.

Generally speaking, among the stockmen of this region the cause of the loco disease has been ascribed to certain leguminous plants known as the loco weeds, the chief of these being *Astragalus mollissimus* and *Aragallus lamberti*. During the last quarter of the nineteenth century this subject was investigated by a large number of people, but with very contradictory results. Attempts were made to isolate a poison from the loco plants, which succeeded apparently in the hands of certain authors, but the results of their work were not corroborated by others. Scientific men traveled largely through the loco region to observe conditions, and autopsies were made on a considerable number of animals. While it was evident that a disease of some kind was causing enormous losses through this semiarid country, the general result of the investigations of scientific men was to lead them to be very skeptical in regard to the supposed poisonous properties of the loco plants. It was noticed that most of the so-called locoed animals had been subjected to an unfavorable environment, especially in the way of feed, and the consensus of opinion among investigators seemed to be that some cause for the disease must be sought other than the loco plants. Some of the stockmen themselves were very skeptical in regard to the poisonous properties of the plants, and contended that with proper feed there would be no such thing as locoed animals.

Inasmuch as the losses were so heavy and the stockmen were anxious to have the subject investigated more thoroughly, the United States Department of Agriculture instituted an experiment in the summer of 1905 upon a larger and more thorough scale than had been

attempted before, hoping to prove or disprove the poisonous properties of the loco weeds. This experiment consisted in feeding cattle and horses upon pastures containing loco weed in comparison with others fed on pastures that were free from the loco weed, as well as feeding the loco plants in the corrals, and of making as extensive autopsies upon locoed animals as possible.

The experiments were intended (1) to prove whether the loco weeds would poison or not, (2) to demonstrate the symptoms of loco poisoning and the pathological lesions accompanying it, and (3) to determine whether or not remedial measures could be instituted for the relief of the loco-infested area.

The conclusions reached as the result of the work of three seasons are as follows:

1. There is no longer any question in regard to the poisonous properties of the loco plants. It was clearly demonstrated that animals eating these plants would succumb sooner or later to their poisonous action. This work, too, was abundantly corroborated by the pharmacological work of Doctor Crawford in the laboratory at Washington, by whom a poison was separated which was fatal to rabbits.

2. It was found that the symptoms of the loco disease were essentially like those which had been mentioned by the majority of stockmen. It was found that some of the symptoms were exaggerated, but, on the whole, the statements of the stockmen were amply corroborated. The more prominent symptoms are a staggering and uncertain gait, caused by a general disturbance of the nervous system, which leads in some cases to an apparent partial paralysis of the limbs and to a very distinct lack of muscular coordination. The animals eating loco eat more and more of it, although they do not in all cases acquire a passionate love for the weed, and sooner or later lose flesh and die of starvation.

3. In the post-mortem examinations it was found that there were certain quite definite lesions. The animals were strongly anemic. This anemia was indicated not only by paleness of flesh and actual loss of blood, but by serous deposits in various parts of the body. The blood was found to be poor in hemoglobin and commonly rather rich in leucocytes. A diseased condition of the stomach was a common accompaniment of the locoed condition, this being marked in cattle by ulcers in the fourth stomach. All the body fluids are rather unusually abundant, and this is particularly true of the fluid of the epidural space of the spinal canal, which is commonly more or less organized, so that the spinal canal frequently seems to be filled with a jelly-like substance. There is a hyperemic condition of the central nervous system, which in acute cases is accompanied by clots in the lateral ventricles. In females diseased ovaries are common.

4. The common loco plants in Colorado and adjacent territory are *Aragallus lamberti* and *Astragalus mollissimus*. Of these the more widely distributed is *Aragallus lamberti*, commonly known as the "rattleweed" or "white loco." The results of the experiment showed very clearly that *Astragalus mollissimus* was much the more virulent of the two species under consideration. This plant is more abundant in the southern part of the semiarid region, although not confined to that. In Colorado it is commonly found in the depressions and on adobe soil, while *Aragallus lamberti* is found upon the hillsides and upon sandy soil. *Aragallus lamberti* is not only common on the plains, but also extends in the mountains to an altitude of perhaps 8,000 feet.

5. Horses, cattle, and sheep are somewhat differently affected by these plants. In regions covered with *Astragalus mollissimus* the only common locoed animals are horses. Horses which eat this plant become poisoned ordinarily rather quickly and may die in a comparatively short time. Both cattle and horses eat *Aragallus lamberti*, but cattle, perhaps, rather more freely than horses, so that in regions where *Aragallus lamberti* is the more common loco plant the cattle are much more commonly affected than horses. In localities where *Astragalus mollissimus* is the only loco plant locoed cattle are very rare, indeed. Sheep eat both species, but for them also *Aragallus lamberti* is the more dangerous, inasmuch as they are more apt to eat this plant than *Astragalus mollissimus*.

6. It was found that there is a great difference in the individual susceptibility of animals to the loco poison, although most of them will succumb to the temptation and perish from its effects sooner or later. In regard to different breeds of animals there is a distinct difference, although the observations were not extensive enough for any broad generalizations. Generally speaking, the better-bred animals are more likely to be poisoned than those that have become accustomed to the country. Among sheep, black-faces yield much more quickly than Merinos. Among cattle, Durhams and Aberdeen-Angus were found to yield more quickly than Herefords.

7. In regard to remedial measures, the work of the experiment gives quite definite suggestions. It is clear that where land is sufficiently valuable to make it profitable to pay for that amount of labor, it is entirely feasible to cut out all of the loco weeds. This is particularly easy in regard to *Astragalus mollissimus*, because it grows in comparatively small patches. Where *Aragallus lamberti* is abundant the work would be more difficult, and in some cases the land is hardly worth the expense of the labor. It is evident that in the case of fenced pastures it frequently will be profitable to destroy the loco weeds in this way.

In the case of open range it is probably impracticable to arrange any means of doing this.

In many cases much can be accomplished by keeping animals away from ranges covered with loco during the time when feed is short, inasmuch as they are much more likely to contract the habit when other feed is lacking. Sometimes it may be profitable to feed for a short time, in order that the habit may not be formed.

It is absolutely necessary that animals which have acquired a taste for loco should be removed from temptation.

Except in very advanced cases, the treatment of locoed animals can be undertaken with every reason to expect good results. The first essential, of course, is to remove to a pasture which is free from loco. Their feed should be so regulated as to produce looseness of the bowels, or if this can not be done they can be dosed with some laxative, such as magnesium sulphate. Green alfalfa is one of the best feeds. If the animals are being fed on grain, it is well to mix oil meal with the grain. The necessity of producing a loose condition of the bowels can not be too strongly emphasized.

Some animals will recover under this treatment without recourse to medicine. With most animals, however, recovery is hastened by the administration of strychnin or sodium cacodylate, or both, in the case of cattle, and of Fowler's solution in the case of horses. All these medicines should be given in small doses and continued for a considerable period of time, seldom less than thirty days. The daily doses of strychnin should not exceed three-twentieths or four-twentieths of a grain (or 0.009 to 0.012 gram). Sodium cacodylate should be given in daily doses of 6.2 grains (or 0.4 gram). The strychnin and sodium cacodylate are best given by hypodermic injection. Fowler's solution should be given in doses of 15 to 20 c. c. in the grain or in the drinking water.

Recovery will in most cases be slow, as should be expected from the slow incipience of the disease; but care will bring the animal to a practical cure in the majority of cases. Cured animals do not seem as likely to eat the loco again, but it is best not to subject them to temptation.

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